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Stellar SOFIA

Southern Hemisphere missions mark new day for the program

X-Press
Address: P.O. Box 273, Building 4839
Edwards, CA 93523-0273
Phone: 661-276-3449
FAX: 661-276-3566

Editor: Jay Levine
Jacobs/Tybrin, ext. 3459

Managing Editor:
Steve Lighthill, NASA

NASA Chief,
Strategic Communications: Kevin Rohrer

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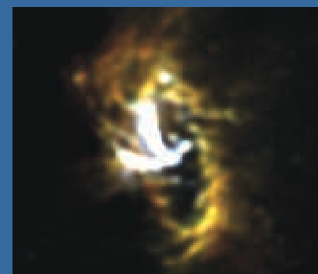
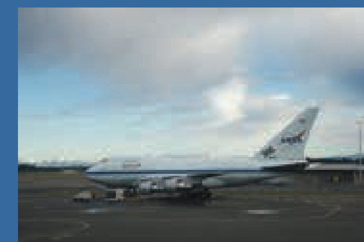




NASA photos ED13-0220-066, above, and cover photo ED13-0220-127 by Carla Thomas

A job well done

Fly 6,900 miles each way, deploy a cadre of flight- and ground-crewmembers along with an international science team for three weeks, and during that time fly three nights per week, 10-hours per flight, while conducting world-class science. It's a lot to imagine and even greater to have accomplished it all.

To meet our program goals set earlier this year, the Stratospheric Observatory for Infrared Astronomy, or SOFIA, departed the United States on July 12, for the first leg of its deployment to Christchurch, New Zealand. Having stopped for a flight crew change and some Hawaiian hospitality from the good folks at Joint Base Pearl Harbor-Hickam outside of Honolulu, the observatory arrived the following morning at Christchurch where preparations began for the first of nine science missions.

Water vapor in the Earth's atmosphere is extremely low during the winter months over the southern oceans, which provides an ideal environment for infrared astronomy. The fact that water vapor interferes with infrared observations was key to our decision to base the observatory at Christchurch. Contributing to that decision was the infrastructure provided by the U.S. Antarctic Program, which is operated by the National Science Foundation, or NSF, from the Christchurch International Airport. During our deployment, the NSF opened its facilities to us, and they, along with everyone at the Christchurch International Airport, were most gracious hosts.

While we were on New Zealand's southern island, our team was supported by the U.S. State Department and U.S. Ambassador to New Zealand and Samoa David Huebner and his staff who are based in the capital, Wellington, on the northern island. I'd also like to extend a special note of appreciation to all of the New Zealanders who were very interested in our mission and made our team feel most welcome.

For our flights from Christchurch we planned a series of observations using the German Receiver for Astronomy at Terahertz Frequencies, or GREAT, instrument that were proposed by a combination of astronomer guest investigators plus members of the GREAT consortium. A team from the Max Planck Institute for Radio Astronomy, Bonn, Germany, developed the GREAT instrument, which is a spectrometer that detects the wave aspect rather than the particle aspect of infrared light. Among its many other capabilities, GREAT helps astronomers measure the chemical composition of star forming regions and supernova remnants. For this deployment we spent the majority of our time observing the Milky Way Galaxy's central regions and the Milky Way's companion dwarf galaxies known as the Magellanic Clouds.

Measuring the chemical composition of the interstellar medium in the Magellanic Clouds enables astronomers to infer conditions right after the "Big Bang" because the material of the clouds has not been recycled through many generations of stars forming and dying. Even though this material has been floating in space for millions of years, it is considered relatively "fresh" and in an unprocessed state. SOFIA's access to this material means our observatory can, in effect, do cosmology research without the need to make measurements of galaxies billions of light years away. This capability is very exciting to our science staff and the worldwide astronomical community.

SOFIA's entirely successful deployment to New Zealand, completed on Aug. 2, was very important to our program. We demonstrated the capability to operate the world's largest, airborne astronomical observatory with high efficiency and reliability, achieving 100 percent of the planned science flights. By all accounts the quality of the scientific data was also outstanding. The international deployment team did an excellent job planning and safely executing every logistical and operational detail, and those of us "left behind" worked hard before and during the deployment to support them. Completing our first scientific deployment is a key accomplishment in our transition to becoming a fully operational observatory.

This cadence was especially challenging to achieve while on deployment and demonstrates that SOFIA is on track to achieving the anticipated Full Operational Capability that will allow the flight rate seen in New Zealand to become routine.

Congratulations to the entire team for this outstanding achievement.

Eddie Zavala
NASA's SOFIA program manager

ED13-0267-08 NASA/Tom Tschida

Zavala, from left, Ames Research Center Associate Center Director Deborah Feng and Dryden Director David McBride welcome Troy Asher, Dave Fedors and the SOFIA team members as they returned from the New Zealand deployment.

Eddie Zavala is the program manager of the Stratospheric Observatory For Infrared Astronomy, or SOFIA, program. In this position, he is responsible for overall development and operation of the SOFIA Science Center at Ames Research Center, Moffett Field, Calif., and the airborne observatory, which features a German-built 2.5-meter infrared telescope mounted in a highly modified Boeing 747SP aircraft located at Dryden.

The program is a cooperative effort between NASA – including Dryden and Ames research centers – and DLR, the German Aerospace Center. The SOFIA is the agency's next-generation airborne observatory, which will enable astronomers routine access to the infrared and sub-millimeter portions of the electromagnetic spectrum of the universe.

Expectations

Officials are pleased with the SOFIA team's progress

By Jay Levine
X-Press editor

SOFIA program officials said the New Zealand deployment exceeded their expectations.

"SOFIA's first Southern Hemisphere deployment was a huge milestone for the program and a triumph for the NASA and DLR teams," said Andrea Razzaghi, deputy director of the Astrophysics Division at NASA Headquarters. "SOFIA's newly-demonstrated ability to observe the Southern skies will allow it to study an exciting collection of astronomical targets."

The mission also featured another key accomplishment.

"It was a fabulous deployment and a tremendous success with its nine observations," Razzaghi said. "The deployment increases our confidence in the capabilities of this observatory. It is proving to be a reliable observatory that will provide opportunities for scientific investigation for many years to come."

Erick Young is the SOFIA's Science Mission Operations director and was key in deciding what science would be attempted during the New Zealand deployment. Young, who is based at NASA Ames Research Center at Moffett Field, Calif., said the conditions for science were excellent.

"One of the main reasons for SOFIA is to get above most of the water vapor in the Earth's atmosphere. During the deployment we saw some of the lowest water vapor levels ever seen with SOFIA. That means the clarity of the atmosphere at infrared wavelengths was outstanding," Young said.

The flights also demonstrated SOFIA's operational capability.

ED13-0303-01 NASA/Ken Ulbrich

NASA officials said they are happy with the results of the New Zealand deployment. From left, are Dryden Director David McBride: Andrea Razzaghi, deputy director of the NASA Astrophysics Division: Eddie Zavala, SOFIA program manager: Alois Himmes, DLR SOFIA project manager: Glenn Wahlgren, NASA Headquarters SOFIA program scientist: and John Gagosian, SOFIA program executive based at NASA Headquarters.

ED13-0267-08 NASA/Tom Tschida

Zavala, from left, Ames Research Center Associate Center Director Deborah Feng and McBride welcome Steve Robinson, a SOFIA crew chief.

"The team conducted three consecutive flights a week for three weeks in a row. This flight cadence is close to what we will need to operate at the maximum anticipated flight rate and shows that the operations team is ready. The quality of the science results from the deployment will also send strong signals to the scientific community."

Alois Himmes, DLR SOFIA project manager, said the SOFIA partnership is what made the mission successful.

"Communication is very good despite the distance we have," Himmes said. "We rely on telecons and e-mail when we are not here and the cooperation onsite with the contractors, Dryden and Ames is very good. All of us function like an integrated team."

The first and early science flights with SOFIA have already led to a number of published papers, Himmes said. He expects that the observatory updates and upgrades will continue to enhance science opportunities, as proven by the New Zealand deployment.

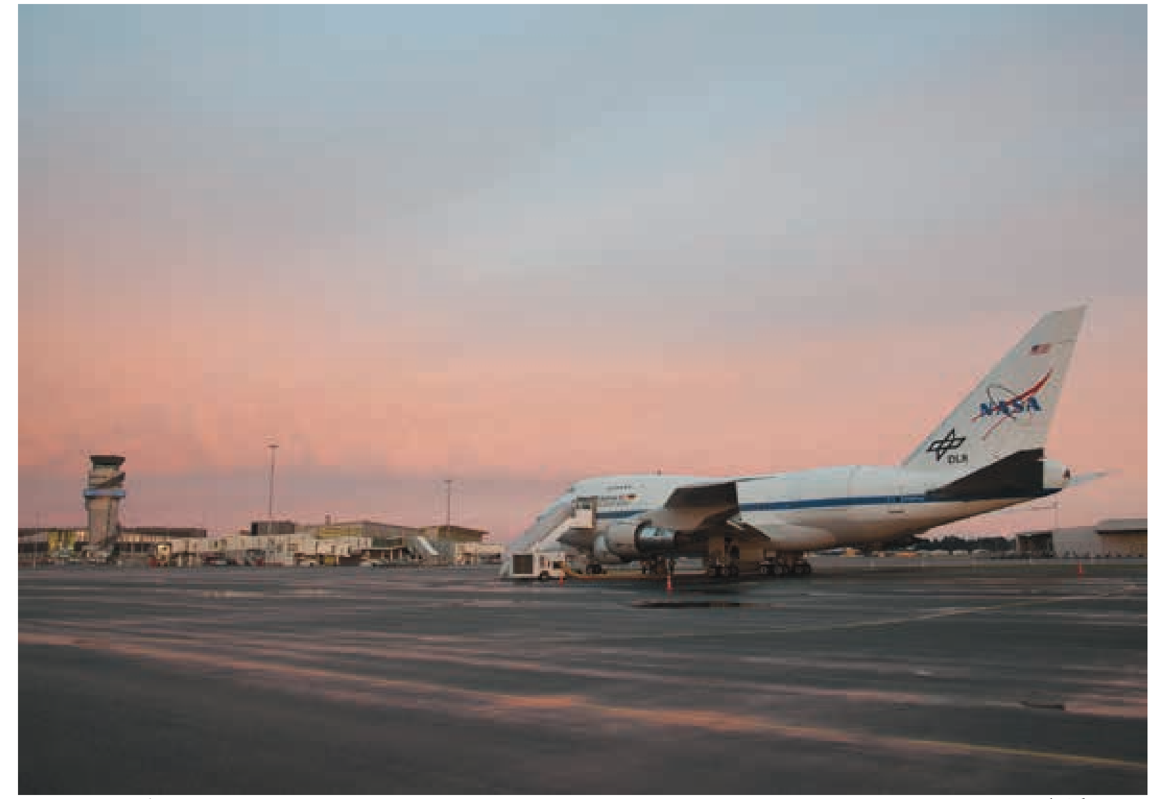
"I am very satisfied with SOFIA, especially with a difficult deployment in New Zealand that went very well. They planned nine flights and all nine flights took place to the minute they were planned. The conditions in New Zealand were excellent for infrared observations. The scientists said it was close to the conditions in space, perhaps that is an exaggeration, but it was very good," Himmes said.

John Gagosian, who is the SOFIA program executive based at NASA Headquarters, said the deployment exceeded all of his expectations.

"I know we have a great team here and in the past it has really come through when the pressure was on," Gagosian said. "I was expecting we would get good results, but the fact that 100 percent of the objectives were met was really amazing and we at NASA headquarters are very pleased."

Two elements of the New Zealand deployment stood out.

"We had our first observations of some very compelling targets in the Southern Hemisphere," he said. "We executed nine science flights over the course of 14 nights, which is by far the most rapid sustained operational period that we have had. The combination of demonstrating SOFIA's capability to observe these very valuable scientific targets and its ability to observe them at a fast tempo, really make this a huge milestone for the program."



ED13-0220-263 NASA/Carla Thomas

The SOFIA is on the tarmac in Christchurch, New Zealand. The team met 100 percent of the science goals for the Southern Hemisphere mission.

ED13-0220-263 NASA/Carla Thomas

The SOFIA NASA 747SP aircraft crew was treated to this view of the aurora australis, or southern lights.

The missions to date are just a glimpse of what is to come.

"SOFIA is designed as a general purpose observatory," Gagosian said. "The science on SOFIA is driven by the most important scientific questions that are raised by the community. We have built it to be versatile and we built it with a wide variety of instruments that can observe a huge spectrum of wavelengths. What we found in other observatories is that the scientific questions we thought they were going to answer were only a small portion of what ultimately was discovered. There are new questions that will be raised and that will be answered, but we don't even know what those are yet."

Glenn Wahlgren, who is the NASA Headquarters SOFIA program scientist, said observations with SOFIA are critical to learning about the formation of stars and even the development of our Milky Way galaxy.

"As other instruments come on board we are going to be able to observe not just the objects we are observing now, but other objects of interest in a manner we will be seeing for the first time," Wahlgren said. "It is very exciting with new developments in instrumentation on board and the new science that is going to come out of these."

He also said partnerships, such as NASA's collaboration with the European Space Agency on the Herschel Space Observatory mission, are providing additional groundwork for interest in SOFIA. The airborne observatory can make similar observations with instruments such as the GREAT instrument used in New Zealand.

"The claim that we can go anywhere to conduct our science certainly was validated by this deployment," Wahlgren added.

There are additional advantages to science aboard SOFIA.

"SOFIA can be thought of like a ground-based observatory in that the instruments can be changed. There is a technology development aspect of the mission where technology can be tested on SOFIA flights until it has been matured to the point where it can be proposed to fly on other NASA missions," Wahlgren added.

On the inside

By Jay Levine
X-Press editor

Before the Stratospheric Observatory for Infrared Astronomy NASA 747SP took to the skies for its first deployment to the Southern Hemisphere, the aircraft underwent complex modifications and maintenance to optimize the observatory's capabilities.

Initial "Early Science" missions in late 2010 and 2011 permitted a solid look at the observatory and its systems. From there, decisions were made to determine what could be improved during the major maintenance and modifications in 2012 to prepare the observatory to shift from developmental to operational, said Brent Cobleigh, SOFIA platform project manager.

Science flights this year include commissioning of SOFIA's first science instruments (see related articles on the science), which so far are performing well. SOFIA managers were relieved the telescope's main mirror was returned to pristine condition following a cleaning without anticipated recoating and telescope system improvements were successful.

Updates to the aircraft's mission command and control system were the biggest bulk of the work in 2012. The MCCS includes essentially all of the observatory systems other than the telescope on the massive NASA 747SP. Concerning the German-made telescope, dozens of changes were made to the telescope assembly software to correct errors, improve efficiency, monitor systems and warnings, increase capabilities and improve pointing and tracking performance (see related article).

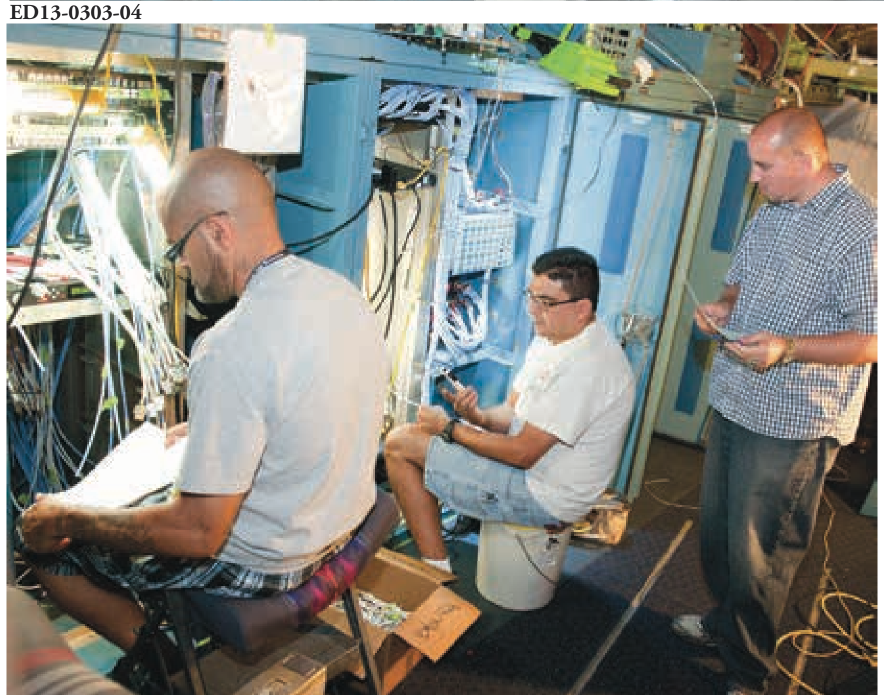
Previously, aligning the telescope with nearby stars and calibrating the science instrument was how astronomical phenomena were seen. It was a challenge in areas of the sky where there were no stars bright enough to use for accurate pointing and tracking. However, a new focal plane imager camera, with detectors dozens of times more sensitive than the original camera has vastly improved the telescope's performance. Now much dimmer stars can be used to point and track the telescope – in fact about 96 percent of the sky – to observe astronomical items of interest.

"The current angular pointing error is about 0.5 arc seconds. It's like being able to target an object the size of a nickel 5.5 miles away," Cobleigh said. "Being off one degree in that example would be the equivalent of the distance of a 40-story building."

Observatory improvements to the water vapor monitor included autonomous operation and the ability to provide data real time. Another key improvement was to add a data archiver. Once comprised of lots of smaller data recorders all over the aircraft, the centralized archiver has a storage capability of up to nine-terabytes with a backup in case of a failure. In addition, its disk packs can be taken right off the aircraft for analysis and new disk packs can be readied for the next mission, he explained.

A massive re-wire of the aircraft was necessary – more than 15,000 wire connections – to integrate the many new systems and be prepared for several important upgrades over the next few years. A key objective was to allocate the power required for the next generation of science instruments, Cobleigh added. The power available for science instruments has more than tripled with these modifications and the aircraft is now able to integrate cryogenic coolers. Instead of constantly refilling liquid nitrogen, future instruments will recycle liquid nitrogen in a loop, like an air conditioner, he explained.

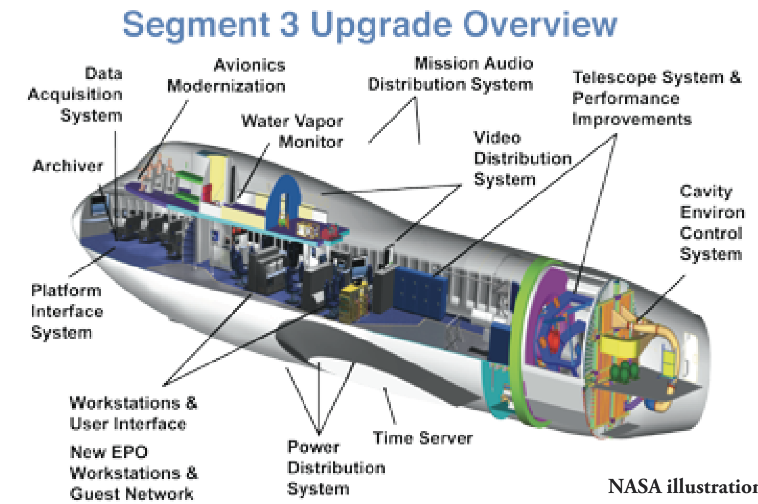
ED13-0303-04 NASA/Ken Ulbrich



ED12-0104-056 NASA/Tom Tschida

***Above**, a number of key SOFIA platform managers are pictured including Kevin Weinert, front row, from left, Daryl Townsend and John Baca. Second row from left is Mike Collie, Steve Robinson and Tim Krall (on the stairs). Back row, from left, are John Spooner, Ting Tseng, Bill Condzella and Brent Cobleigh.*

***At left**, Theodore Brooks, from left, Frank Lightbourn and Gustavo Carreno IV verify instrumentation and network installations and modifications.*



NASA illustration

The illustration of the NASA 747SP shows the key modification and maintenance work.

ED12-0368-02 NASA/Tom Tschida

The NASA 747SP received an avionics modernization in 2012. Most of the analog gauges and associated hardware were replaced by digital, computer-based systems with multi-functional "glass cockpit" displays.

ED07-0078-037 NASA/Tony Landis

This 2007 photo shows the NASA 747SP cockpit in the original configuration as built in 1977.

The cavity environmental control system was also upgraded for better performance. The cavity has to be kept dry when the aircraft descends in order to prevent water vapor from condensing and freezing the telescope mirrors. The upgrade allows the ground crew to more quickly warm up the mirrors from the minus 40 degrees Fahrenheit that is encountered at 45,000 feet altitude back to temperatures on the ground.

Also part of the improvements was the addition of an education console, intended for use by programs like the Airborne Astronomy Ambassadors (see related article). The Airborne Astronomy Ambassadors program is a yearly professional development opportunity extended to educators through a competitive, peer-reviewed process. Teams of two educators are paired with groups of professional astronomers to experience a SOFIA mission first hand. The console allows educators to see the same displays as the mission director and telescope operator.

The cockpit received a major upgrade from 1970s analog data, dials and gauges that were mostly replaced with what's called a 'glass cockpit.' The glass cockpit features electronic screens capable of displaying whatever information the pilot wants to see.

"It was quite a challenge," Cobleigh said. Specifically, marrying state-of-the-art cockpit systems to the 1970s systems on the one-time airliner were difficult, he added.

Another improvement is the new weather radar that can help the aircraft stay out of turbulent areas, as well as a new radio and navigation system. A separate satellite system provides additional communications abilities for worldwide operations and air traffic and ground avoidance features. A long-range antenna was mounted on the aircraft's vertical tail to improve communications with air traffic control during long flight segments over the ocean. The new cockpit is more reliable and maintainable, as replacement parts are easier to acquire for the updated

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Science of the SOFIA

By Jay Levine
X-Press editor

Science conducted aboard the Stratospheric Observatory for Infrared Astronomy was intended to provide astronomy observations and data that are simply out of this world.

So far, the NASA 747SP observatory that carries the world's largest airborne infrared telescope has delivered some of the clearest infrared imagery obtained of astronomical objects of interest, said Eric Becklin, SOFIA chief science advisor. Ultimately, science aboard the SOFIA could provide clues to questions such as can life form in space?

SOFIA has distinct advantages over telescopes on Earth because it flies above the atmosphere that obscures infrared observations. It also does something that isn't currently possible with space-based assets – it can change instruments for different missions and validate the most cutting-edge technology, while using it for science.

"SOFIA is absolutely living up to its expectations, especially on the deployment to New Zealand," Becklin said. "We are doing unique science that can't be done any other way. The New Zealand missions represent the best nine flights of the SOFIA program to date. Everything worked as expected and many new science results were recorded."

The SOFIA missions in the Southern Hemisphere, which were based in Christchurch, New Zealand in July and August, allowed observations of astronomical objects of interest that can't be seen as well – or at all – from the Northern Hemisphere.

"A major part of the Milky Way galaxy we can't see in the Northern Hemisphere," Becklin explained. "So you have to go down there to see that part of the Milky Way. Two nearby galaxies, called the Large and Small Magellanic Clouds, are actually satellites, or companions to the Milky Way. They can only be studied by going down to the Southern Hemisphere."

ED13-0220-145 NASA/Carla Thomas

Eric Becklin, SOFIA chief science advisor, points out how the telescope tracked a dust cloud in the center of the Milky Way galaxy.

Many findings from the New Zealand missions are not available yet. It takes from one to three years for most major science discoveries to be confirmed and verified before the results can be published, but Becklin gave an overview of some of what the SOFIA missions observed.

Scientists studied a molecule they didn't know if they would encounter, but hoped they would.

"We studied the deuterated hydrogen molecule, which contains a heavy hydrogen atom," Becklin said. "The GREAT instrument analyzed it with a significant increase in sensitivity and spectral and spatial resolution than ever before."

From the very first observations with the telescope on May 26, 2010, all indications were that SOFIA was going to be an excellent airborne observatory when its first images of Jupiter were captured using Cornel University's Faint Object Infrared Camera for the SOFIA, or FORCAST, instrument. That activity is referred to as "first light." Then FORCAST was used again on the first science mission in December 2010. For that mission, the telescope peered into the nearby Orion nebula that is undergoing a burst of star formation and regions where stars are forming in the Milky Way galaxy.

The flight marked the first time since the Kuiper Airborne Observatory that a telescope in an aircraft completed a science mission. Becklin worked on the KAO, which was based at NASA's Ames Research Center in Moffett Field, Calif., for 14 years.

The KAO ended 20 years of service and groundbreaking science in 1995 with the intention that SOFIA would be developed to further redefine what is possible with an airborne telescope. It was a long wait, but well worth it, he added.

The first use of the German Receiver for Astronomy at Terahertz Frequencies, or GREAT, in April 2011 was another milestone. The instrument is a high-resolution, far-infrared spectrometer that divides and sorts light for detailed analysis. Some of the key targets of that observation were the IC342, a spiral galaxy located

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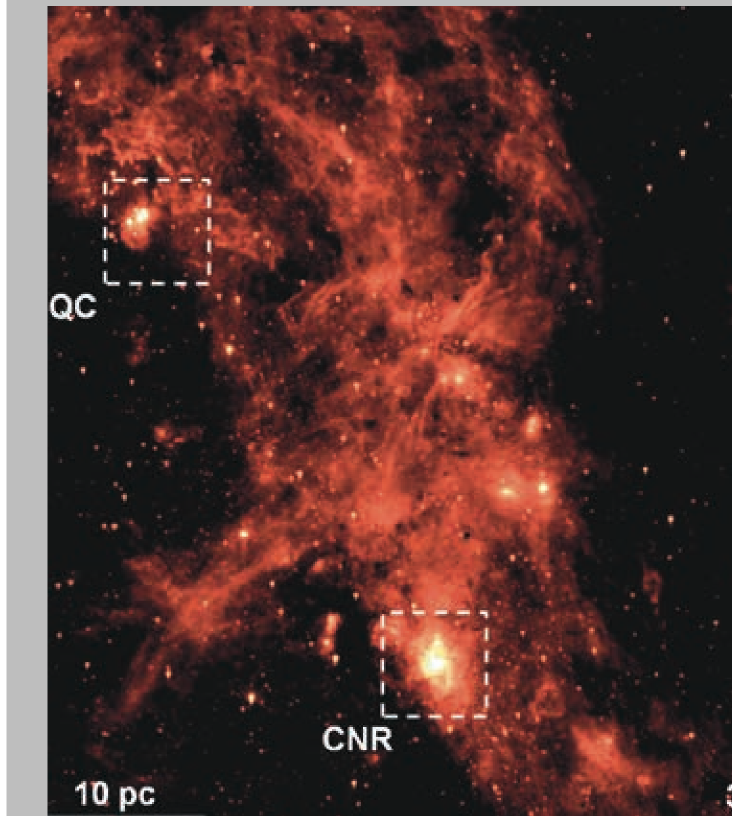
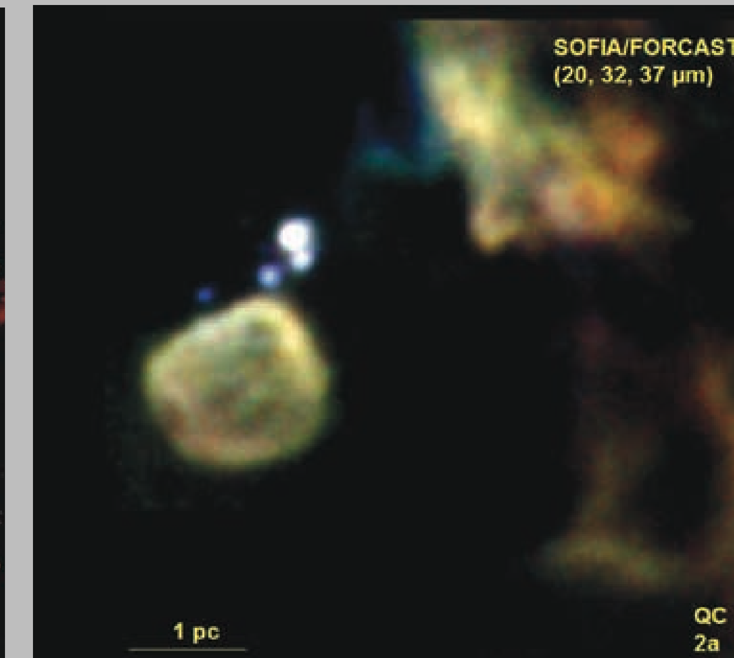


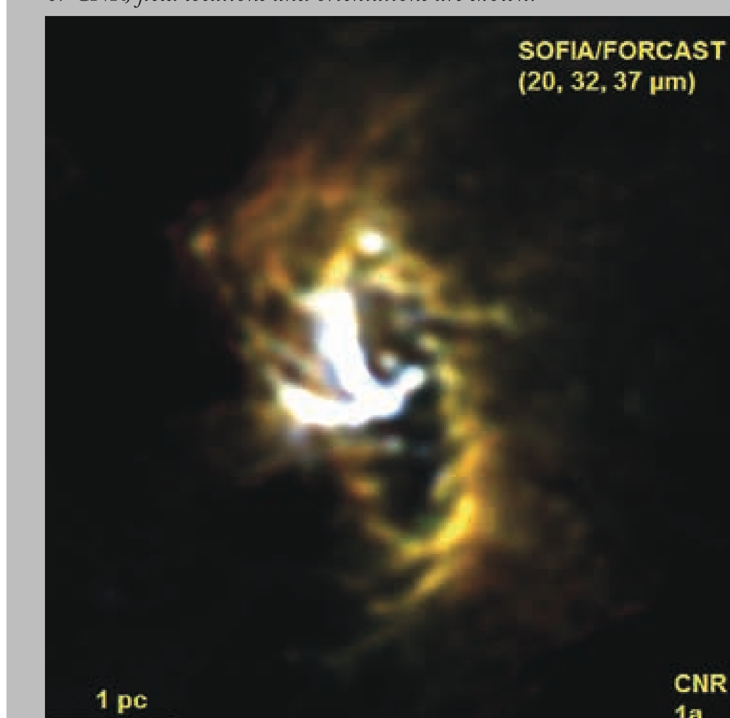
NASA/Spitzer/Caltech-JPL

Spitzer Space Telescope wide-field image of the galactic center of the Milky Way at a wavelength intermediate between those of the SOFIA/FORCAST and Hubble Space Telescope Near Infrared Camera and Multi-Object Spectrometer images. The Quintuple Cluster, or QC, and Circumnuclear Ring, or CNR, field locations and orientations are shown.



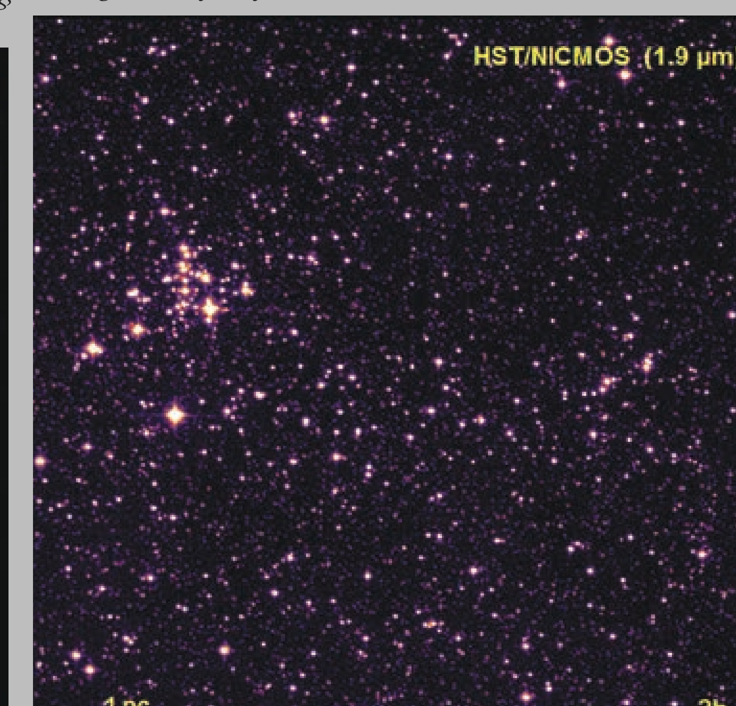
NASA/SOFIA/Hankins et al. 2013

SOFIA/FORCAST mid-infrared image of a region including the Quintuple Cluster (QC), a group of young stars located about 35 parsecs (100 light years) from the galaxy's nucleus. The compact bright objects rendered white and blue in this image are dust cloud "cocoons" heated from within by the highest luminosity stars in the cluster to temperatures that make them prominent at mid-infrared wavelengths. Other features in this image are interstellar clouds of gas and dust. The large rounded oblong feature below the QC is an expanding cloud of debris produced by violent ejections of material from a massive star nearing the end of its life.



NASA/SOFIA/FORCAST team/Lau et al. 2013

This is a SOFIA/FORCAST mid-infrared image of the Milky Way galaxy's nucleus showing the Circumnuclear Ring of gas and dust clouds orbiting a central supermassive black hole. The bright Y-shaped feature is believed to be material falling from the ring toward the black hole located where the arms of the "Y" intersect.



NASA/STScI

This Hubble Space Telescope Near Infrared Camera and Multi-Object Spectrometer image shows the Milky Way's Quintuple Cluster, or QC, region matching the SOFIA/FORCAST field of view infrared images. The QC is the bright cluster on the left side of the image. Most of the features in the SOFIA mid-infrared image are not seen in the HST image due to their low temperatures and intervening interstellar dust.

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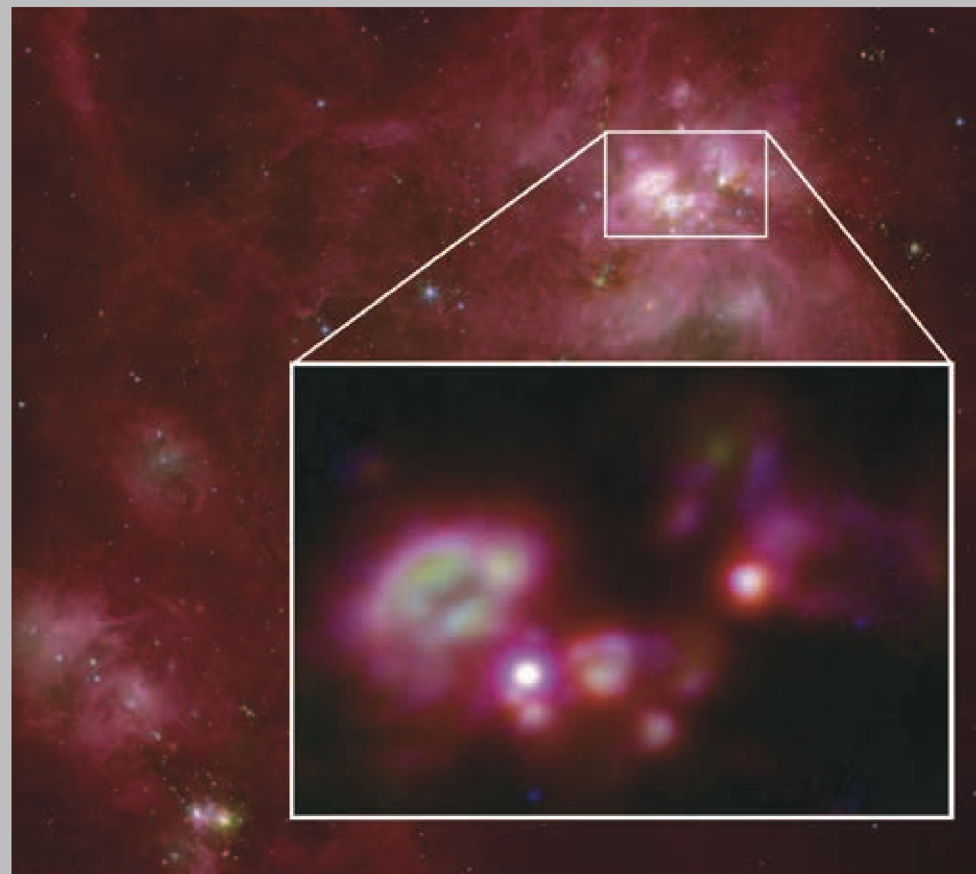
11 million light years from Earth and the Omega Nebula, known as M17, which is 5,000 light-years away. GREAT is the instrument used during the New Zealand deployment.

"The GREAT instrument spreads the infrared radiation further than any other instrument," Becklin said.

"When you spread it further you get more detail about what molecules, or what atoms, are being detected, but you also get Doppler information that can tell you whether a gas or molecule is coming toward you or moving away from you. In addition, it also allows you to start developing the physics of what is happening where you are looking. In particular, it allows researchers to start looking at the density of the material that they are studying and its temperature. The GREAT instrument does this well," he said.



At left, this mid-infrared image of the W3A star cluster in the inset was captured by the FORCAST camera on the SOFIA flying observatory in 2011. It is overlaid on a near-infrared image of the W3 star-forming region from the Spitzer space telescope.

SOFIA image: NASA/DLR/USRA/DSI/FORCAST team Spitzer image: NASA/Caltech - JPL

Using the GREAT instrument on an earlier mission, two new molecules that were previously identified but had never been seen before in the material in between stars were observed. The first is sulfur and hydrogen together and the other was oxygen and deuterium together.

SOFIA was used to observe the Pluto occultation in June 2011, which entailed the dwarf planet passing in front of a distant star. The occultation enabled scientific analysis of Pluto and its atmosphere when SOFIA was dispatched at the right moment to the exact location where Pluto's shadow fell on Earth.

Some of Becklin's favorite moments have included observations of star formation at the core of the Orion nebula.

"It was known to be a nursery where stars are born. We were able to make SOFIA observations with the best image quality that's ever been made of this region. We had some surprises. Observations from the ground cannot tell the whole story, but SOFIA observations gave us insight into what actually is going on," he said.

And studies of the massive black hole in the center of the Milky Way have been enlightening.

"We were surprised with the spectacular image of dust that is circling around that black hole. It's a ring that we knew about, but we did not know the interesting details. It's dust and gas orbiting around the black hole and we are seeing the dust in the images, but the GREAT team also saw the gas that is rotating around and made measurements," he said.

Flying the missions and gathering the data is often just the first steps of discovery Becklin said.

"Once in a while you know when you land that you have something interesting, but it takes a year to two years to fully analyze it and to make sure you haven't made a mistake. That you make sure that you have everything calibrated so you're not just talking about speculation based on the image or that one spectrum where you know what's physically happening out there," he explained.

Science on SOFIA has been so good that two U.S. industry publications highlighted the program including the "Astrophysical Journal" and the "Journal of Astronomy & Astrophysics."

It's uncertain what the next discovery will be with SOFIA, but what is certain is the best is yet to come.

ED10-0336-33 NASA/Tom Tschida

Jim De Buizer, lower right, studies data with FORCAST principal investigator Terry Herter, left. In the background, Eric Becklin and Mark Morris, right, look on during preparations for SOFIA's initial science flight.

Ambassadors

Teachers and researchers team up for education

By Beth Hagenauer
Dryden Public Affairs

Twenty-six educators from across the United States are experiencing the ultimate classroom aboard the Stratospheric Observatory for Infrared Astronomy, which flies its missions about 43,000 feet above Earth.

As participants in the Airborne Astronomy Ambassadors program, the educator teams of two have been partnered with professional astronomers using SOFIA for scientific observations in 2013. They were selected in January 2012 for research flights aboard the airborne observatory.

SOFIA is a modified Boeing 747SP jetliner equipped with a 100-inch (2.5-meter) diameter telescope. The observatory enables the analysis of infrared light to study the formation of stars and planets; chemistry of interstellar gases; composition of comets, asteroids and planets; and supermassive black holes at the centers of galaxies.

"The unique design of SOFIA gives educators hands-on experience with world-class astronomical research," said John Gagosian, SOFIA program executive at NASA Headquarters in Washington, D.C. "Working with astronomers, educators participate in a research project from beginning to end and integrate that unique perspective with classroom lessons and public outreach programs."

As the date grew close for their flight aboard the observatory, two Airborne Astronomy Ambassadors from El Paso, Texas, said they were so excited that they had trouble sleeping.

Adriana Alvarez and Mariela Aguirre, teachers at Alicia R. Chacon International School, arrived June 9 in Palmdale, Calif., the location of SOFIA's home base at the Dryden Aircraft Operations Facility. Alvarez's excitement partly originated from a childhood "NASA game" she played with her father. Alvarez's now-deceased father taught her the names and locations of the constellations and talked about NASA research. She carried those memories aboard SOFIA, feeling her father's presence.

Melvin Gorman and Gordon Serkis of Chinle Junior High of Chinle, Ariz., joined Alvarez and Aguirre on the June 11 flight.

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ED13-0181-28 NASA/Carla Thomas

Karina Leppik, from left, Adriana Alvarez, mission manager Charlie Kaminski and Mariela Aguirre, observe mission information.

ED13-0174-55 NASA/Jim Ross

Jo Dodds of Twin Falls High School in Idaho, left, and Coral Clark and Ralph Peterson of North High School in Bancroft, Idaho, view on screen information.

Success in New Zealand

SOFIA records milestones

ED13-0220-178 NASA/Carla Thomas

ED13-0220-149 NASA/Carla Thomas

At left, the Stratospheric Observatory for Infrared Astronomy NASA 747SP is parked on the ramp in Christchurch, New Zealand. The program had a successful first deployment to the Southern Hemisphere that included nine science missions in three weeks and achieved 100 percent of the science goals. ***Above****, SOFIA team members are pictured during the deployment at the Christchurch Airport. The mission was based at the airport where an outpost for the U.S. Antarctic Program that isn't active in the area's winter season was available. The U.S. Antarctic Program uses Christchurch as a staging area for sending people and supplies down to the McMurdo Station, which is a U.S. Antarctic research center.*

ED13-0220-424 NASA/Carla Thomas

Michael Ritchson, from left, Rainer Strecker, standing and Stefan Teufel, seated, discuss options to best meet requirements for adding telescope documentation to the SOFIA portal database.

ED13-0220-349 NASA/Carla Thomas

Above*, Bill Wohler, standing, Gabrelle Saurage, seated, Alan Hatakeyama, and in the foreground is Helmuth Wiesemeyer work during a mission.* ***At right****, Manny Antimisiaris, left, James Less, right, and Martin Trout, rear, keep SOFIA on course.*

ED13-0220-318 NASA/Carla Thomas

GREAT

Science instrument is proving its value flight by flight

Karl Jacobs, Oliver Ricken and Urs Graf work to prepare the GREAT instrument for a mission.

ED13-0220-145
NASA/Carla Thomas

By Jay Levine
X-Press editor

As the Stratospheric Observatory for Infrared Astronomy redefines our knowledge of what is out in space, it will be key new instruments on its telescope that will make it happen.

One such instrument is the German Receiver for Astronomy at Terahertz Frequencies, or GREAT, which was installed on the NASA 747SP for the July deployment to Christchurch, New Zealand.

"The science was spectacular. The atmosphere was so dry that for many observations it was like being in space," said Rolf Güsten, principal investigator for the GREAT instrument. Güsten, who is based at the Max Planck Institute for Radioastronomy in Bonn, Germany, referred to one of the key advantages of having an infrared telescope located in an airborne observatory – it is above the atmosphere that obscures infrared viewing from Earth.

"GREAT is not a camera, it is a spectrometer," explained Urs Graf, a senior scientist at the University of Cologne, Germany. "We can look at the spectral distribution of the light that is coming in with very high accuracy and very high spectral resolution so we can identify individual types of molecules and atoms that are in space based on their spectral 'fingerprint.' To do this, we use technologies that are developed from radio frequencies all the way into the terahertz range and there are essentially no other instruments around that can do it."

In addition to identifying molecules and atoms in space, high spectral resolution also can measure if the molecules and atoms are moving away from researchers or toward them. Seeing chemistry and dynamics in space are the specialties of the GREAT instrument, Graf explained.

Prior to the New Zealand deployment, the GREAT instrument was enhanced. Designed in a modular way, the team can take advantage of the dramatic improvements in terahertz technologies and integrate them into the GREAT instrument.

"We have installed more sensitive detectors, more powerful oscillators which are needed to combine, or 'mix' the astronomical signal and much improved resolution bandwidth of the spectrometer that now provides more than 100,000 resolution elements per detector channel," Güsten said.

What that means is the sensitivity of the instrument has almost doubled, which equals twice the science opportunities with better data at the same operation costs, Güsten explained.

Modifications have also enhanced the instrument in other ways.

"Beyond its better sensitivities the improved GREAT has a wider reception bandwidth, allowing observations of signals from nearby galaxies like the Magellanic Clouds. For our deployment flights out of New Zealand we pushed our technological frontiers even further into new territories and higher frequencies, aiming at the detection of the unique hydrogen deuteride molecule. Deuterium, 'heavy hydrogen,' only produced in the Big Bang, serves as a chemical clock of the evolution of the universe," Güsten explained.

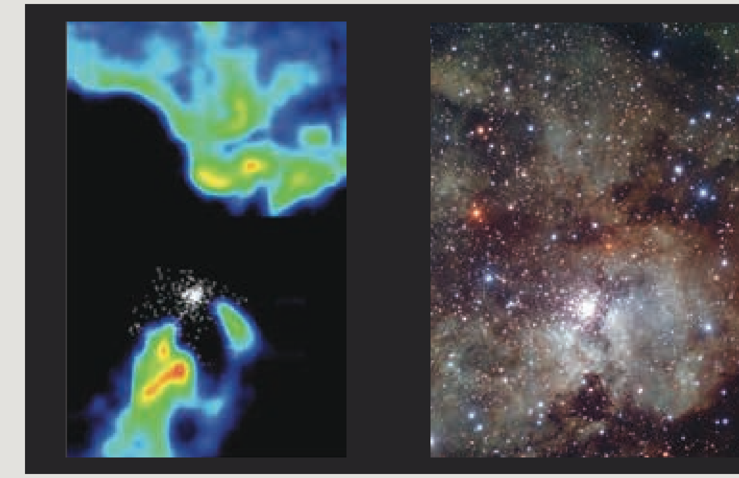
"On Earth, deuterium accounts for only .02 percent of all hydrogen, in space even 10 times less. Therefore, the most sensitive state-of-the-art instrument is needed to hunt for this molecule, and because its frequency footprint cannot be observed from ground. Only GREAT on a high-altitude flight with SOFIA can perform these observations," he said.

GREAT's work has been recognized for the volume of science it has helped complete on SOFIA.

"The observations with GREAT were very successful. Almost 30 papers have been published since the completion of the early science flights. The renowned European Journal 'Astronomy & Astrophysics' dedicated a special volume in July 2013 to the first science results, thereby acknowledging the science impact of GREAT/SOFIA," Güsten said.

"Highlights are definitively the detection of two molecules in space: emitting at far-infrared wavelengths, they could only be detected with SOFIA. Next, we studied the accretion disk orbiting around the massive black hole in the center of the Milky Way, showing that the structure is

Great, page 16



Left image: NASA/GREAT team Right image: European Southern Observatory

The prominent star-forming cloud NGC3603, a nursery for stars, is only visible from the Southern Hemisphere. GREAT observed the cloud in the sixth flight from Christchurch, New Zealand. The two images compare the far infrared sky to the optical view. The GREAT image shows the emission of ionized carbon as seen with GREAT (red is bright emission) compared with an optical image of the same region. The cluster of bright stars seen in the optical image is young – only a few million years old. The emission of the ionized carbon, in contrast, traces dense gas condensations with ongoing massive star formation and are still invisible at optical wavelengths.

ED13-0220-155 NASA/Carla Thomas

Michael Toberman congratulates Rolf Güsten on the first successful science mission flown from New Zealand.

ED13-0219-106 NASA/Tom Tschida

Urs Graf, senior scientist at the University of Cologne, Germany, works on installation of the GREAT instrument onto the telescope housed in the SOFIA flying observatory.

ED11-0030-43 NASA/Tom Tschida

GREAT principal investigator Rolf Güsten, left, and GREAT team member Graf discuss preparations for SOFIA flights on a previous mission.

GREAT... from page 15

transient and cannot survive for long against the strong gravitational forces, ultimately feeding the black hole," Güsten added.

Of the two molecules located in space with SOFIA, one is composed of sulfur and hydrogen and the other had oxygen and deuterium together.

The New Zealand mission offered new opportunities for the GREAT instrument.

"The deployment was fabulously successful. We completed more than 25 science projects during this series of nine consecutive research flights. Heavy emphasis was placed on studies of the Large and Small Magellanic Clouds, which are close neighbor galaxies to the Milky Way, but only visible from the southern skies. They have been intensively studied at optical wavelengths, but there have been few opportunities to view the two dwarf galaxies that are widely unexplored at the far-infrared wavelength. GREAT advanced our knowledge about the star formation processes on galactic scales," Güsten said.

Plans for future improvements to the GREAT instrument are underway.

For the November flights, the team is preparing to integrate the "high frequency" channel of GREAT. The channel will operate at 4.7 THz, which almost doubles its operating frequency. Today's GREAT operates two detectors at a time, each tuned to a different sky frequency. Extending GREAT into a detector array would multiply science opportunities. The German Space Agency (DLR) has agreed to co-finance the upgrade of GREAT and "upGREAT" is expected to be available in 2015.

Güsten expressed gratitude to the SOFIA management team.

"Not only due to its success was this deployment a very pleasant experience. It gave us a little taste of what we expect when SOFIA is ramped up to its full flight capacity. It has been a pleasure to see the complete team's determination toward our common objective: achieving the best possible science – from the ground crew to the flight deck, we all shared all the joys and challenges of far-infrared astronomy.

"I have been involved in many projects and I know the importance that teams understand science is the mission's goal and Eddie (Zavala, SOFIA program manager) and his team are definitively committed to this," Güsten said.

Speaking of commitment, the instrument's team is always thinking of ways to improve it.

"With SOFIA, your instrument is never finished," Graf said. "When your instrument is working, you already have ideas of how to improve it."

No doubt GREAT and the stable of SOFIA instruments will continue to improve. As the instruments get more advanced, so too will the ability of researchers to collect information to answer key questions about the molecules and atoms that make up the cosmos.

Courtesy of Rolf Güsten

Prior to the SOFIA's first science mission in New Zealand, the GREAT team posed for this image. Front row, from right, are Patrick Puetz, Miguel Requena, Bill Wohler, Christophe Risacher, Helmut Wiesemeyer and Yoko Okada. In the back row, from right, are Ed Chambers, Oliver Ricken, Rolf Güsten, Karl Jacobs, Stefan Heyminck, Bernd Klein, Juergen Stutzki, Urs Graf and Robert Simon.

Ambassadors... from page 11

They were four of 15 Airborne Astronomy Ambassadors who flew that month and interacted with astronomers and mission managers during night missions lasting almost 10 hours each.

Dan Ruby, who was aboard SOFIA June 25, is one of two informal educators from planetariums to be selected as an ambassador. The purpose of his outreach at the Fleischmann Planetarium in Reno, Nev., is to engage people in the field of astronomy.

"The public perception is that astronomy is dead. It really is not," Ruby said. Many consider astronomy to be enjoyed by "really nerdy people sitting in a dark room looking at stars," he added. What the SOFIA telescope looks at is cool and the fact that it takes place on a plane is engaging. "This is really exciting. The same way that rockets and shuttles are exciting," Ruby added.

Ruby's teammate Matt Oates of the Dilworth STEM Academy in Sparks, Nev., has developed a number of projects for middle school students including high-altitude ballooning. He applied for the Airborne Astronomy Ambassador program as a means to further encourage his students.

Carolyn Bushman of Wendover Junior/Senior High School in Wendover, Utah, flew on the June 25 SOFIA flight with Ruby and Oates. She appreciated the opportunity to watch a team of NASA professionals and planned to tell her students the importance of teamwork. Bushman's students live in a small, isolated community. She will encourage the students to find something they love and then throw themselves into their work to be the best at what they do.

"NASA changed my life. My experiences have given me a lot of confidence," said Bushman. "I want to teach the students to believe in themselves and reach for the stars."

Bushman's teammate David Black is a teacher at Walden School of Liberal Arts in Provo, Utah. Black first heard of the SOFIA program 10 years ago and he wanted to be involved. When younger, he aspired to be an astronaut. He is fascinated by astronomy and loves flying in planes. For those reasons, this NASA experience is the ultimate – although SOFIA's 45,000-foot maximum altitude does not qualify him for astronaut wings.

SOFIA's Airborne Astronomy Ambassadors effort is an annual professional development program extended to educators through a competitive, peer-reviewed process. The goal is to improve teaching, inspire students and inform the public. The program builds upon the legacy of NASA's highly successful Flight Opportunities for Science Teacher Enrichment, or FOSTER, program that flew educators aboard the Kuiper Airborne Observatory from 1990 through 1995.

The effort also has an international element. The German SOFIA Institute, or DSI, at the University of Stuttgart, manages the German component of the Airborne Astronomy Ambassador program. Four German educators are slated to fly aboard the airborne observatory this coming winter.

The Airborne Astronomy Ambassadors come from a variety of disciplines, grade levels and locations. Regardless of their differences, the experience gained by participating in the ambassadors program feeds their knowledge and enthusiasm for frontier scientific research and advanced aeronautical engineering. This enthusiasm will be shared with students and communities who have the opportunity to learn from someone with first-hand experience about how science, technology, engineering and mathematics are all applied to the real-world applications found in SOFIA.

Inside... from page 7

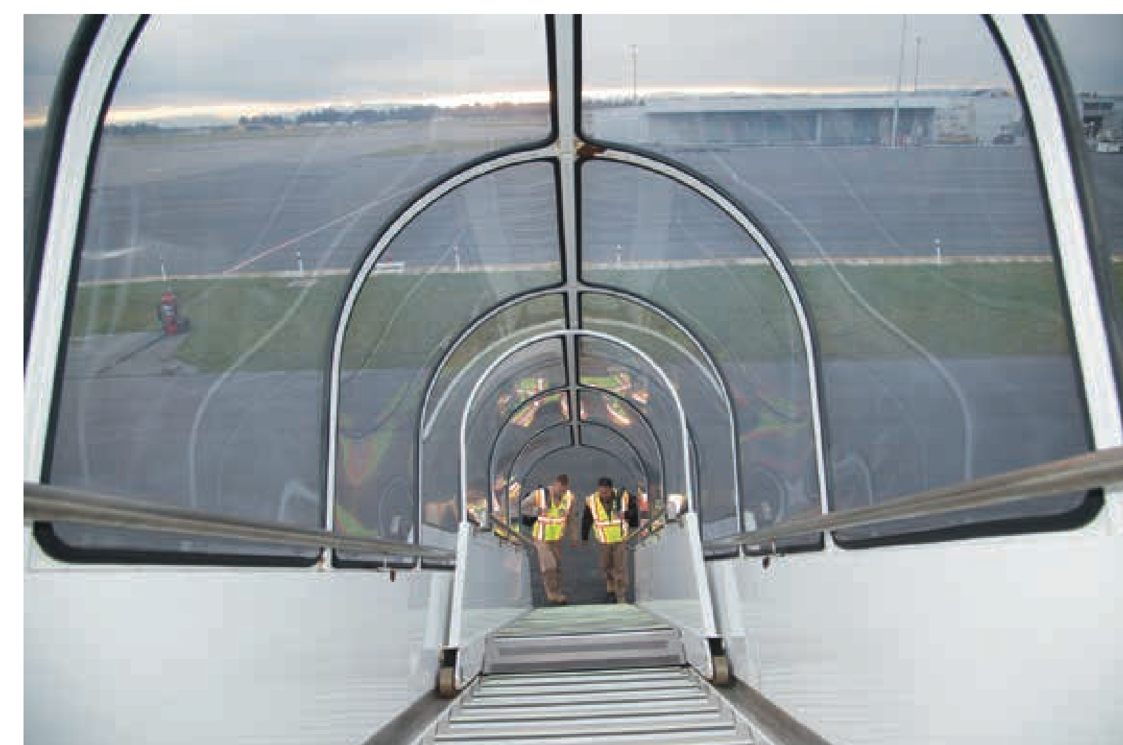
equipment, he added.

The maintenance and modifications are bringing the program close to meeting its intended science mission goals of flying four times per week, every week. During the New Zealand deployment, the aircraft flew three consecutive days for three straight weeks to demonstrate it is ready to embark on a schedule similar to what is envisioned for the observatory.

Getting SOFIA prepared for the deployment took a team effort.

"Two to three shifts were necessary to have all of the new software, systems and integration complete, but everything came together," Cobleigh said.

While it is unknown what SOFIA's next great discovery will be, one thing is for certain – the observatory and its staff will be ready to make it happen.



ED13-0220-279 NASA/Carla Thomas

SOFIA flight crew members James Less, left. and Manny Antimisiaris climb the stairs of the flying observatory.

Explanations

Marcum expounds on questions about SOFIA's science

The Stratospheric Observatory for Infrared Astronomy, or SOFIA, excites many with its science exploits. Followers wonder about the science, what scientists are planning and how missions are chosen. Pam Marcum, SOFIA project scientist, answered some of these questions recently for X-Press editor Jay Levine.

As SOFIA project scientist, what are the main elements of your work?

As SOFIA project scientist I provide government oversight on the science of the mission. In particular, my primary responsibilities are to assure that the SOFIA mission meets its science requirements and that the commitments made to the science community are met. If any course adjustments are needed along the way, then my job is to develop recommendations to mitigate the problem and optimize SOFIA's science return. My position is probably best described as science advisor to the guy who holds the purse strings, the SOFIA program manager.

NASA/Jay Levine

Pam Marcum, SOFIA project scientist, recently answered some questions about the SOFIA's science.

Can you give me a picture of the key upcoming flights over the next several years and what the main science objectives will be?

Curiously, no one on the SOFIA science team could ever know the answer to this question. The reason? Unlike some other NASA missions built with a laser-focused intent to answer a specific science question, SOFIA is a general observing facility built to address a wide range of science objectives. The astronomical community through an annual proposal competition drives the direction of SOFIA science.

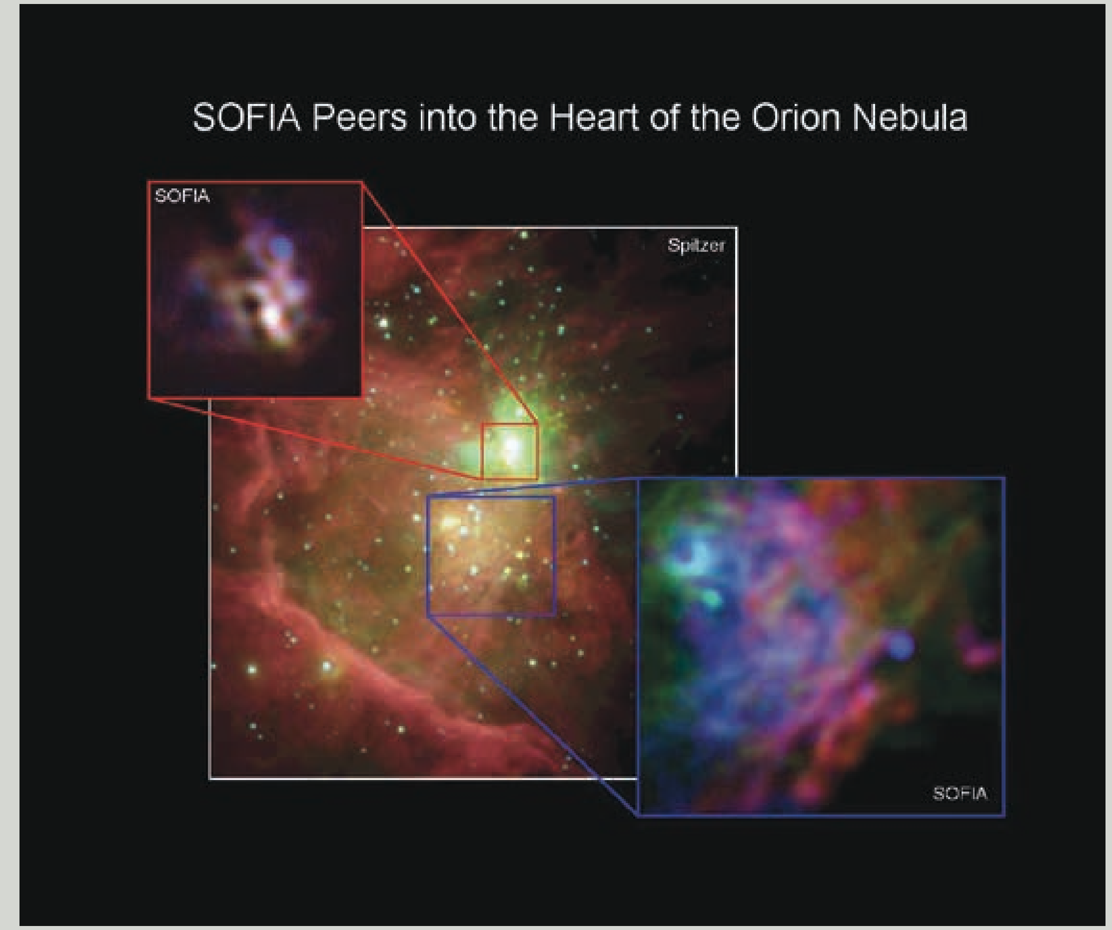
The proposal evaluation is performed by review panels composed of astronomers drawn from the general community. Serving on a proposal review panel is somewhat the astronomer's equivalent of doing jury duty, but culminates in observing time being awarded to the proposed investigations that rank high in addressing compelling science. The SOFIA staff plan the science missions that SOFIA will conduct based on those proposals, one year at a time. One exciting aspect of SOFIA is that we never know what kind of innovative questions may suddenly emerge that could take the science in a completely new and unexpected direction. Given the nature of infrared astronomy, and in lieu of a crystal ball, we can make a somewhat general prediction: investigations into the detailed physics of the star forming process will likely feature prominently in SOFIA science over the next several years.

Planning a year at a time must allow for the latest and greatest instruments to be used as well as the questions of the day in astronomy?

Awarding observing time annually, selecting the cream of the proposed science and incorporating emerging new technologies into the science instrumentation that collects SOFIA data ensures the observatory is able to evolve as the science evolves, sustaining its relevance in addressing the "latest and greatest science."

This approach, science one-year-at-a-time, is not unique to SOFIA. In fact, the annual evaluation/selection of science investigations is the modus operandi of nearly all large ground-based observatories and of most of the large space-based telescopes. Compared to these space-borne facilities, SOFIA's greatest advantage is that cutting-edge technologies can be incorporated into new science instruments and installed on SOFIA to help keep up with the rapidly expanding envelope of science knowledge. The space telescopes are largely stuck with the era of technologies that they were launched with and may not be able to keep up with the "latest and greatest" questions simply because they are hampered by the constraints of those old technologies.

The latest round of SOFIA observing proposal reviews has been completed for Cycle 2. The cycle observations for a given cycle begin around February of each year and end around November/December of that same year. The Cycle 2 proposal call is closed, but Cycle 3 call for proposals will be released around the March to April 2014 timeframe.



SOFIA image James De Buizer/NASA/DLR/USRA/DSI/FORCAST; Spitzer image NASA/JPL

This graphical representation from the SOFIA Science Center compares two infrared images of the heart of the Orion nebula captured by the FORCAST camera on the SOFIA airborne observatory's telescope with a wider image of the same area from the Spitzer space telescope.

What is your impression of the science obtained during the New Zealand deployment?

I have not seen the data, so I can't comment first-hand. But everything that I have heard from the deployment team is positive. The ultimate demonstration of the quality of science, of course, will be in the resulting publications. It will take a while for the observing teams to analyze their data and write the associated science papers.

Is there any general information you can discuss about the nature of what was learned?

Observations of star forming regions in the satellite galaxies that orbit about our own Milky Way galaxy, the Large and Small Magellanic Clouds, as well as observations near the center of our galaxy, were the primary focus of the deployment observations. These regions are located in the southern part of the sky, and are therefore "under the horizon" (or very close to it, as in the case of the Galactic Center) from Palmdale. The deployment to the Southern Hemisphere allowed these science targets to be high above the horizon and therefore readily visible and accessible by the SOFIA.

How pleased are you about the flight rate demonstrated during the New Zealand deployment?

Extremely pleased. The quick turnaround of the aircraft and observatory was executed in a flawless manner, with all systems working well and supporting each other. The first attempt at this higher flight rate was tremendously successful!

Two SOFIA instruments have not yet flown. I presume that's because they are still in development. What is the status of the Echelon-Cross-Echelle Spectrograph, also known as the UC Davis-developed EXES, and the JPL High-resolution Airborne Wideband Camera, or HAWC?

The EXES instrument is completing its development and will be commissioned and used for observations by the science community during Cycle 2 in 2014. HAWC was a first-generation instrument that was selected for major overhaul during the second-generation science instrument selection process. This upgrade, which includes a larger and more sensitive detector and the ability to measure polarization in astronomical targets, will significantly increase the science capabilities of this instrument. HAWC, which has been promoted to second-generation instrument status, is now known as "HAWC+" and will be commissioned during Cycle 3 in 2015.

Are you pleased with the science achieved with the SOFIA so far?

To answer this question, let's review the science products from SOFIA to date. Analysis from the first set of science flights from November 2010 to December 2011, dubbed "Early Science," has resulted in more than 30 journal publications. Some of those papers describe new approaches in measuring certain types of astrophysical phenomena, utilizing mid-infrared images taken at unprecedented resolution, and announcing at least two "firsts" in the observation of particular molecules in interstellar space.

The science observations completed during Cycle 1 will most certainly have a similar science return in the form of published results. I am pleased with the results to date, especially considering the fact that the telescope still was in development when these data were acquired and therefore was not at the peak performance it will be operating.

SOFIA houses the largest flying infrared

Telescope

By Jay Levine
X-Press editor

It's a challenge to keep a telescope pristine and ready to make new discoveries when it's located on the Stratospheric Observatory for Infrared Astronomy and flying at altitudes up to 45,000 feet. A door in the side of the massive NASA 747SP that houses the telescope opens during missions, which is one reason that housekeeping chores can pile up.

"It's like dusting your house – it never ends," said Geoffrey Ediss, a SOFIA engineering lead.

Studies with SOFIA's telescope and instruments are expected to give new perspective on the universe, but to do that it's vitally important to have the telescope mirrors clean, Ediss said.

"We just 'washed' the mirror and that went very well. We try to keep the cavity where the mirror is located as clean as possible. During missions all sorts of dust gets into the cavity and lands on the mirror. It gets dustier and dustier so we have to clean it now and again," he added.

Other challenges also contributed to the mirror's need for attention.

"The door was not 100 percent sealed against water early on and we had some water land on the mirror that left stain marks. As part of that washing process the stains came off. The mirror was left in beautiful condition without having to recoat it," Ediss said.

It's been a learning experience on each flight, but preparations for a SOFIA deployment to Germany in 2011 were particularly troubling.

"In the stratosphere temperatures in the insulated cavity have been recorded down to about minus 60 degrees Celsius. The focus changes slightly with temperature as parts of the telescope shrink, so we measure temperature," Ediss said. "Before that deployment, temperature sensors located behind the telescope's main mirror were found to be causing cracks in its glass. The sensors were removed, the cracks were repaired, the mirror was returned to pristine condition and a lesson was learned. Following this discovery, the sensors were reattached using new methods that have resulted in no additional challenges."

NASA/Jay Levine

Above, Jean-Michael Meyer, from left, Andreas Reinacher and Geoff Ediss review displays at the telescope assembly control console on board the Stratospheric Observatory for Infrared Astronomy NASA 747SP aircraft.

ED13-0008-16 NASA/Jim Ross

At left, NASA Science Mission Directorate Chief John Grunsfeld, left, and an unidentified telescope technician examine the framework supporting the 100-inch primary mirror in the telescope cavity of NASA's SOFIA flying observatory.

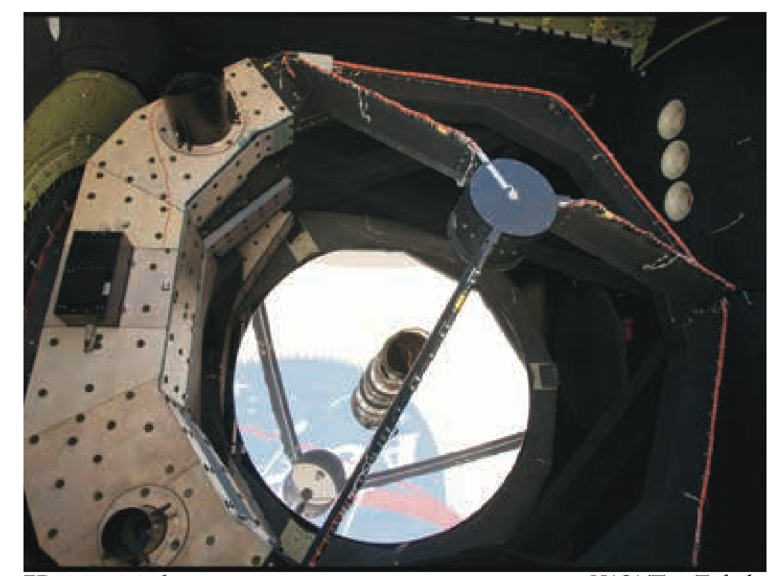
ED08-0067-24 NASA/Tom Tschida

At left, the 2.5-meter infrared telescope in the rear fuselage of NASA's 747SP SOFIA flying observatory is illuminated. The image shows the scale of the cavity where the telescope is housed. The door remains closed until the aircraft has reached the altitude and conditions for its use. The door was open on the ground for tracking the star Polaris during characterization tests in March 2008.

Below, the NASA logo on Bldg. 703 at the Dryden Aircraft Operations Facility in Palmdale is reflected in the 2.5-meter primary mirror of the world's largest flying infrared telescope. The telescope is housed in the SOFIA NASA 747 aircraft.

SOFIA has an international partnership to make its science possible. NASA handles the job of the 747SP that houses the telescope (see related article) and the German Aerospace Center, or DLR, is responsible for the telescope. DLR is similar in Germany to what NASA is in the United States. In addition, the German SOFIA Institute, or DSI, is their contractor and is located at the University of Stuttgart in Germany. DSI has three teams in Palmdale to provide maintenance on the telescope, including items like changing the seals; logistics, such as securing spare parts; and engineering, he explained.

Key servicing tasks and upgrades were completed to improve the function of the world's largest flying infrared observatory prior to the New Zealand deployment. To enable the best science opportunities, the ability to better target astronomical objects of interest and follow them as the observatory moves is paramount to success. To those ends, a new focal plane imager was installed.



ED11-0173-076 NASA/Tom Tschida

"We can point the telescope more accurately because it gives us better tracking and pointing information. We have to know what the science instrument is 'seeing' to calibrate that with the object of interest because that's what the scientists are seeking," he said.

The imager improvements allow for better visibility of fainter objects and a larger area of the sky to line up what is seen with the science objective.

"The imager works by splitting off the visible light from the same spot in the sky and putting that into a charged-coupled device, or CCD, camera," Ediss explained. "The high-tech camera can see very faint objects, but the one on the telescope when it was first built was uncooled and did not have the sensitivity we wanted. With the new focal imager we can now see much fainter objects and track stars we couldn't before. It marks a major improvement in pointing on the telescope and our observations."

Another challenge is vibration on the telescope during missions.

"Air coming into the cavity as the aircraft travels at 500 mph creates some vibration on the telescope. To counteract that, there are actuators on the back of the telescope. Those actuators also cause the telescope to vibrate in such a way that in the end all the vibrations cancel and the telescope is very stable," he said.

Improvements will continue on the SOFIA telescope and the flying observatory that houses it as the program continues to move from developmental program to operational science missions. When it takes to the skies for its next mission, one thing is certain – the telescope and its instruments will be ready for cutting-edge science discoveries.

Logistics

Everything must be ready for the mission to succeed

By Jay Levine
X-Press editor

When it absolutely, positively has to be ready to go, whom do you call?

When the location was New Zealand and the platform was the Stratospheric Observatory for Infrared Astronomy, Daryl Townsend had the answers for the aircraft. Townsend, SOFIA aircraft maintenance and logistics chief, had the responsibility of keeping the NASA 747SP ready to fly.

It was the SOFIA program's first deployment to the Southern Hemisphere where the focus was on astronomical phenomenon that can't be seen well – or at all – from the Northern Hemisphere. However, plans were put to the test July 17 when an aircraft system failed that required the rapid delivery of equipment and personnel.

Enter Matt Reaves, who is the SOFIA platform lead instrumentation engineer. When the call came that there was trouble, he headed down to the outpost in Christchurch, New Zealand.

"I had three laptops shipped to meet me in Christchurch that could provide alternate methods of real-time data monitoring. After we found the best locations to place the two required laptops, the avionics technician crew did an exceptional job installing them while still accomplishing their normal maintenance and flight preparation tasks. I reconfigured the data-processing applications and created display pages to meet the bare minimum data monitoring requirements. It took two-and-a-half days to bring back the ability to see the data needed for flight and post flight," Reaves explained.

ED13-0220-209 NASA/Carla Thomas

Michael Toberman discusses with Andrew Fischer plans to divert the SOFIA to Auckland, New Zealand, because of weather concerns during the flying observatory's return from a 10-hour mission.

The logistics staff members must have invested in a 55-gallon barrel of pain relievers, as it's not simple to plan for parts and people to travel halfway around the world. Logistics plans were detailed to cover anticipated challenges and fortunately, Townsend said, there were few major challenges that required items that were not on hand. Had there been those kinds of issues, the logistics plan included expedited shipping, vendors to tap and methods to pay for it quickly. Townsend also credited Valerie Jones, SOFIA maintenance logistics lead and Rosalia Toberman, Dryden Aircraft Operations Facility procurement officer lead, for invaluable work on logistical support.

"We have certain parts identified through experience and through a United Airlines logistics plan that included the failure rate of each component. We put it all together and the components that have a known high failure rate that we can actually repair in the field are in what we call a fly away kit for the aircraft," Townsend said.

When the SOFIA team returns in 2015, Townsend said the challenges with customs in New Zealand will go smoother. The team will benefit from knowing how the customs process works and from relationships developed during this deployment. Townsend said he would also look into improving the ability to meet a more catastrophic challenge, such as developing a capability to have a spare engine available.

The first challenge to a Southern Hemisphere deployment was deciding where to base the SOFIA. Locations early on included South Africa, South America, Australia and New Zealand.

The best case was made for New Zealand, where the Christchurch Airport had an outpost for the U.S. Antarctic Program that isn't active in the area's winter season. The U.S. Antarctic Program uses Christchurch as a staging area for sending people and supplies down to the McMurdo Station, which is a U.S. Antarctic research center.

"They conduct the majority of their research in the Antarctic summer, that's why the facilities in Christchurch are not used in the Southern Hemisphere winter," said Michael Toberman, the acting SOFIA deputy program manager and mission manager for the deployment.

The location made logistics easier on the ground and created a climate for success, he added. Speaking of climate, it was chilly there – 30 and 50 degrees Fahrenheit, he said.

With a location determined, Toberman began to build the foundation of the deployment. Months prior to the deployment, items like aircraft air conditioners, tires, power carts and parts were shipped to the New Zealand destination.

In addition to being the first Southern Hemisphere deployment, flying three missions in three days was a first for the program. This was a feat repeated each of the three weeks they were based in New Zealand, for a total of nine flights. That required two flight crews in order to safely ready the aircraft to fly the following day, Toberman added.

"It takes a lot of coordination with a lot of people," he said.

A non-stop trek from Los Angeles International Airport to New Zealand is roughly 12 hours of flying, he said. Crossing the International Dateline means passengers land in New Zealand tomorrow and return to the U.S. on the same day as they depart from New Zealand.

The mission displayed the SOFIA team's abilities as the program nears the goal later this year of flying up to four missions a week, Toberman said. The observatory and its staff will be challenged as the number of flights and the varied science gears up, but this mission shows that the team is ready for these challenges.

ED13-0220-449 NASA/Carla Thomas

While it was summer in California, where the SOFIA is routinely based, it was winter in the Southern Hemisphere during the New Zealand deployment.

ED13-0220-111 NASA/Carla Thomas

Daryl Townsend, the SOFIA aircraft maintenance and logistics chief, left, and Andres Hernandez, a SOFIA crew chief, wait for a forklift to bring up the cryogenic gases and servicing equipment.