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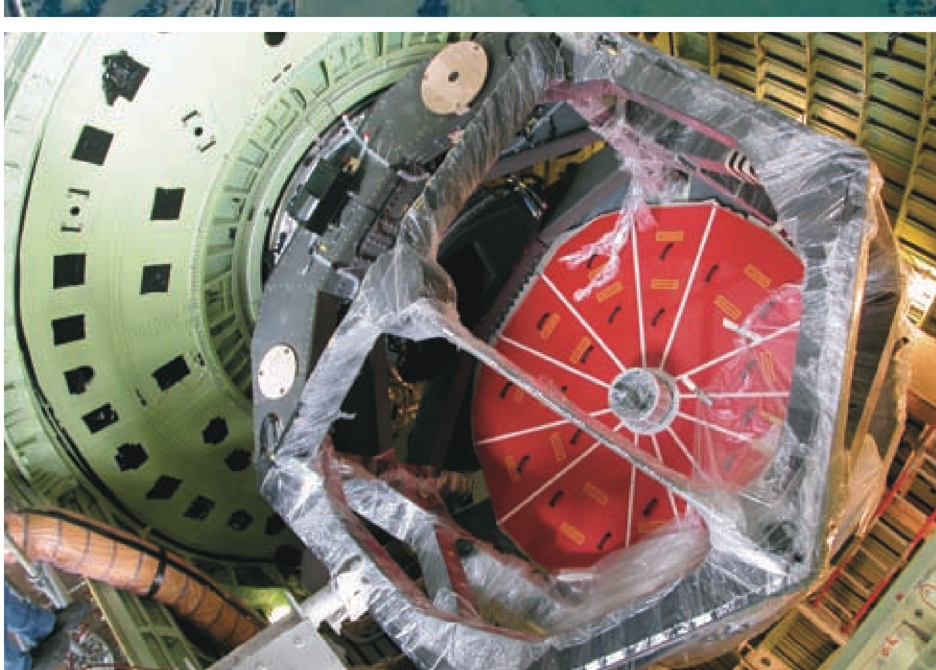
Sensational SOFIA



The SOFIA

Key events may lead to first science data in about 2 years

By Jay Levine
X-Press Editor

The Stratospheric Observatory for Infrared Astronomy, or SOFIA made its debut at Dryden June 27 following three successful checkout flights in Waco, Texas, where major modifications had been completed by L-3 Communications Integrated Systems.

The arrival at Dryden marked a new day in transitioning work with the aircraft from significant modification to the start of flight tests, completion of subsystems integration and, eventually, to the task of exploring the heavens.

The SOFIA still has a way to go before routinely engaging in science flights. Progress is measurable, however, and flight tests that will validate the structural modifications to the aircraft should begin this fall, according to Bob Meyer, SOFIA program manager.

The largest of the extensive modifications involved cutting a sizeable hole in the aft fuselage for installation of the infrared telescope and a special door that will protect it. The first phase of flights will be made with the door to the telescope closed. Later flights will include telescope door-open flights.

The SOFIA project is a joint venture of NASA and the German Aerospace Center, or DLR. NASA provided the Boeing 747SP specially modified aircraft and will conduct flight and mission operations, while the Germans contributed the telescope, which has a primary mirror measuring more than eight feet in diameter.

In addition to the most advanced telescope of its kind – one Meyer calls an engineering marvel – the Germans also provided upgraded engines and subsystems as well as a new coat of paint for the aircraft.

Although it will be years before full-scale science operations begin, Meyer said science flights have been scheduled during the second of three phases of flight tests, when the critical door of the NASA 747SP is ready to be opened in flight. Flight tests are scheduled to take about a year, but installation and integration of aircraft subsystems may take two to three. First observations made with the 45,000-pound telescope system during mission conditions are expected in 2009.

EC07 0105-31 NASA Photo by Tom Tschida

Above, members of the SOFIA program leadership include, from left, John Carter, Ed Austin, Bob Meyer and Eric Becklin. Aircraft and science aspects of the program will be co-managed by NASA's Dryden and Ames research centers, respectively. The SOFIA flies a second checkout flight from Waco, Texas, ***at top****.* ***(NASA photo ED07 100-03 by Jim Ross)***

"As soon as possible, we want a science instrument on the plane to get some science data," Meyer said. "Dryden is working diligently to get the observatory flight-tested, to get to the science as quickly as possible."

With that goal in mind, shifts have been doubled in an effort to accelerate deferred maintenance work and installation of key subsystems and instrumentation, said John Carter, SOFIA aircraft project manager.

With a series of checkout flights already completed – including the flight to Dryden, which did not exceed 20,000 feet in altitude – attention now turns to completing and integration of hardware and motors needed to open and close the door that shields the telescope.

"We've gained a tremendous amount of confidence and understanding of the way the airplane truly works and flies and it has increased our confidence for the next flight phase, in which we're going to expand to the entire SOFIA envelope," Carter said.

Research flights with the telescope door closed may begin as early as fall. After those initial flights it will be about eight more months before the aircraft is flown with the door open, and observatory work can then begin to ramp up.

"We have to have the cavity insulation finished," Carter said. "We have an air duct to an auxiliary power unit that needs to be installed. We'll need to have an initial mission control and communications system, and we'll have to have the cavity door-drive system functioning."

The cavity insulation shields the aircraft's interior against outside temperatures, and reduces the effects of the aircraft's movements during flight on the telescope as well as reducing light reflection that could also impact it, he added.

Some of the most extensive modifications include a 16-foot hole for the telescope door – the largest opening ever made on a 747 –and the re-routing of the aircraft's flight control cables to accommodate the door. Those cables extend to the vertical and horizontal control surfaces. Flight control cables also will be instrumented to measure tension caused by thermal expansion. Another key modification was addition of a bulkhead to reinforce the aircraft's structure.

"It's a tremendous accomplishment to get the airplane here," Carter said. "It's the result of some terrific collaboration among Ames, Dryden, the German Aerospace Center, L-3 Communications Integrated Systems and the Universities Space Research Association," an Ames contractor.

"We look forward to beginning a very exciting trip here, and the most difficult flying tasks are yet to come."

Ed Austin, SOFIA science project manager at Ames Research Center, Moffett Field, Calif., said that Ames has primary responsibility for management and oversight of the observatory's science program, including the missions to be accomplished onboard and the operation of ground facilities. Ames' responsibilities also include the integrated telescope, science instruments and software, and observatory functions.

In addition, as part of Carter's aircraft project, Ames personnel are assisting with the telescope cavity door design work, fabrication of its control system and installation and integration work. Key tasks for the Germans will be telescope checkout and test.

The observatory aircraft will feature several unique systems.

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Lindbergh Legacy

NASA 747SP honors aviator's feat

By Jay Levine
X-Press Editor

Excitement is a cure for apathy and that's what Erik Lindbergh, grandson of famed aviator Charles Lindbergh, believes NASA's new airborne observatory will bring to the world.

NASA's new Stratospheric Observatory for Infrared Astronomy, or SOFIA, is a highly modified 747 airliner that carries a 17-metric-ton infrared telescope system. The SOFIA holds great promise as a desperately needed path to awakening an apathetic public and "lighting them up" with awe-inspiring science, Lindbergh said in remarks at a recent ceremony held at Dryden Flight Research Center.

Lindbergh handled the duties of rededicating the Boeing 747SP SOFIA aircraft as "Clipper Lindbergh," first dedicated 30 years ago when it was a Pan American airliner. Lindbergh's grandmother – Anne Morrow Lindbergh, an accomplished aviatrix in her own right – presided over the original dedication.

Lindbergh rededicated the aircraft at L-3 Communications Integrated Systems in Waco, Texas, on May 21, when a plaque was unveiled commemorating the 80th anniversary of his grandfather's historic transatlantic flight, and then again at the June 27 Dryden event. Modifications made to the plane to ready it as a flying observatory were made at the L-3 Waco facility prior to its flight to Dryden.

ED07 0105-1 NASA Photo by Tom Tschida

Erik Lindbergh, grandson of Charles Lindbergh, unveils a plaque rededicating NASA's SOFIA aircraft as "Clipper Lindbergh." The May 21 event, held in Waco, Texas, marked the 80th anniversary of his grandfather's historic transatlantic flight. The SOFIA will be based at Dryden and will be used for groundbreaking astronomical research.

While at Dryden, the NASA 747SP will undergo continued flight and systems testing for about two years while observatory systems hardware and software are integrated. Program officials expect to conduct the first science missions with the telescope as early as 2009.

Charles Lindbergh's transatlantic flight inspired people everywhere and helped fuel a new perspective on aviation, his grandson said in remarks at the June 27 event. Leaving behind a view of those who flew as daredevils and barnstormers, pilots who would carry passengers came to be seen with awe and respect. Simultaneously, the possibilities commercial aviation held began to emerge.

"What's outstanding about this aircraft, and that connection to the Pan Am naming of Clipper Lindbergh and my grandmother

See Lindbergh, page 14

History Lesson

Modern airborne astronomy began at NASA's Ames Research Center

By Jay Levine
X-Press Editor

Eighteenth-century astronomer Sir William Herschel used a prism to discover infrared radiation and through that discovery determined that the sun emitted infrared light. In his era, the day when future astronomers would board an airborne observatory to view the infrared universe was far in the future.

But a scientist like Herschel, well aware of how dramatically a single discovery could alter people's perceptions about the heavens, might easily have been able to imagine that day. In March 1781 his chance discovery of a new planet, Uranus, proved our solar system was double the size astronomers believed it to be.

Big changes often unfold slowly, however, and it would be nearly two centuries before technology matured enough to allow astronomers equipped with an infrared telescope to travel above atmospheric water vapor. In the 1960s, infrared detectors developed from military heat-seeking missile technology were incorporated into telescopes at scientists' request. Astronomers saw amazing results and a new age of discovery began.

"We started looking at stars, expanded our observations to galaxies and then looked at the core of our own Milky Way, which had not been seen before. It's been a roller coaster of discoveries and discoverers since then," said Ed Erickson, a senior astrophysicist at Ames Research Center in Moffett Field, Calif.

CV-990

Modern airborne astronomy began in 1965 when two scientists, Gerard P. Kuiper and Frederic F. Forbes, used Ames' Convair 990 to study the clouds of Venus. The yellowish clouds were believed to contain water, but scientists using ground-based telescopes were unable to conclusively confirm its presence because water vapor in the Earth's atmosphere obstructed their view.

"Kuiper realized as you get up to aircraft altitude, you could see out of Earth's atmosphere because you get above most of the atmospheric moisture, which blocks most infrared wavelengths," Erickson said. "From the CV-990, Kuiper was able to measure the spectrum of the clouds of Venus in the near infrared and found that they contained essentially no water.

"That was quite an exciting discovery, because then people really wondered what they *were*."

The answer would elude astronomers awhile longer. While the mobile telescope on the CV-990 was adequate for making the determination that Venus' clouds were very dry, the aircraft, also known as the Galileo I, was constantly needed to support other NASA programs. In addition, a windowless or "open port" telescope, not available on the CV-990, would be required to unravel astronomical mysteries that reveal their secrets at longer, far-infrared wavelengths.

Enter the Ames Learjet.

Learjet

Acquiring a dedicated airborne observatory gave researchers more opportunities and options for studying the heavens. In the late 1960s Frank J. Low of the University of Arizona made far-infrared observations with a novel 12-inch open-port telescope, which he had developed for use in an Ames Learjet.

"The telescope didn't have a sealed bearing," said Erickson. "A narrow spherical gap in the mounting flange allowed it to articulate, with cabin air rushing through the gap. Because of that you couldn't pressurize the cabin very much, otherwise the gap would close and the telescope would stick. We had to wear oxygen masks all the time."

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Bill Brockett piloted the Kuiper, page 5

Allan Meyer brings KAO experience to the SOFIA program, page 5

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Lead pilot Gordon Fullerton compares the NASA 747s, page 7

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The SOFIA program's education/outreach element is creating partnerships at 41,000 feet, page 10.

Cover story

The lead image shows the NASA 747SP, which carries an infrared telescope, making its first checkout flight over the skies of Waco, Texas. In Waco, L-3 Communications Integrated Systems employees completed significant modification work prior to the aircraft's transfer to Dryden. *(NASA Photo ED07 0079-2 by Carla Thomas)* Image at bottom left shows the telescope installed inside the NASA 747. The 2.7-meter (over eight-foot) mirror is beneath the red cover. *(Photo courtesy L-3 Communications Integrated Systems)* Bottom right, Eric Lindbergh removes star-spangled bunting from the SOFIA's fuselage to reveal the moniker "Clipper Lindbergh." *(NASA Photo ED07 0140-47 by Tony Landis)*

These infrared images were captured by researchers using the Spitzer Space Telescope and represent the type of astronomical objects that will be of interest to investigators when the SOFIA is fully operational. Above is the Milky Way galaxy, and the Helix nebula is pictured below.

Science of the SOFIA

By Jay Levine
X-Press Editor

The only thing more impressive than an airborne observatory that carries a 17-metric-ton telescope is the potential for equally weighty new breakthroughs in astronomy.

The vast array of science driving work with the Stratospheric Observatory for Infrared Astronomy, or SOFIA, boils down to this: "The most exciting science is really trying to understand the chemistry and, potentially, the biology that's going on in space, and really getting to the heart of the question of, did life form here on Earth, or did it form out in space?" said Eric Becklin, SOFIA chief scientist and a pioneer in the field of infrared astronomy.

The SOFIA alone won't be able to answer the questions of where life began – about 15 scientists will be directly working on the SOFIA science mission – but the airborne observatory will undoubtedly contribute to revolutionary new ways of looking at the universe.

To those ends, as many as another two or three dozen scientists around the world – including about 10 from Germany, a key SOFIA partner – are continuing to push the state of the art in research instrumentation, said Becklin, a 42-year veteran of infrared science. Science data gathered from the SOFIA also will be analyzed by hundreds of additional scientists.

NASA's Kuiper Airborne Observatory, which was based at Ames Research Center at Moffett Field, Calif., for 21 years, was the first of its kind. The SOFIA program is expected to pick up where the Kuiper's work ended in 1995 when that aircraft was retired.

"One of the things that SOFIA can do that Kuiper couldn't do is – because of (the SOFIA telescope's) large 2.7-meter (over eight-foot) aperture, it actually has a clearer view of the universe. We'll have a sharper view. In fact, it will be the sharpest view we'll have at some of the wavelengths we're looking at," said Becklin, who also was a principal investigator aboard the Kuiper. Wavelengths are the sections of the electromagnetic spectrum under which astronomical phenomena can be seen.

The SOFIA will have other advantages compared with those of its predecessor, and will offer capabilities that complement the work of other observatories currently in use.

"Relative to the Kuiper, we'll definitely see deeper into space. Relative to space observatories like Spitzer or ISO we won't necessarily go deeper," he said, referring to NASA's space-based infrared Spitzer Space Telescope and the European Space Agency's Infrared Space Observatory satellite.

"In terms of sensitivity – we'll be more sensitive than the Kuiper, we're about the same as the European space observatory and we won't be as sensitive throughout the infrared as Spitzer, which is flying presently, but our images will be sharper," he added. "We will also make measurements at wavelengths that are not covered by ISO or Spitzer."

In addition, the SOFIA will offer advantages over ground-based assets by "observing" above the water vapor that obscures celestial subjects when they're viewed from Earth. "(Use of the SOFIA) opens up a whole new range of observations in the electromagnetic spectrum that can be observed – that you just can't do from the ground – and that's especially true of infrared," Becklin said.

Observations made in the infrared spectrum offer many advantages over those made through other wavelengths.

"An advantage of infrared is that it 'peers' through the dust that's out in space. There's a lot of dust in space; it's between stars. The view that we get of the universe in the optical or ultraviolet (wavelength) is biased by dust. SOFIA will probe right through that dust," he said.

"In the visible and ultraviolet, you're mainly looking at stars. When you look in infrared you see stars, but also see (more clearly) the dust and the gas that those stars formed from or are throwing off as they die. You really get a different view of the universe when you look in the infrared," added Becklin, who in 1968 completed his doctoral thesis on the exact center of the Milky Way galaxy.

Another of Becklin's achievements includes discovery of the first known protostar (a forming star) in the heart of the Orion nebula, which, along with partner astronomer

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Expanding the frontier

SOFIA will ensure that the KAO's legacy lives on

EC93 0066-3.1 NASA Photo courtesy Lynn Albaugh/Ames Research Center

By Jay Levine
X-Press Editor

In 1977, Jim Elliot and a graduate student, Ted Dunham, left Perth, Australia, to fly out over the Indian Ocean on the Kuiper Airborne Observatory. They were in pursuit of an expected occultation of Uranus by a star bright enough to provide the intensity needed for taking measurements as the planet extinguished the starlight.

Elliot, who today is a professor of planetary astronomy at the Massachusetts Institute of Technology and director of M.I.T.'s Wallace Observatory, was about to make a major discovery by watching the occultation. An occultation is an eclipse of a star by a planet or heavenly body.

"The airplane has to be in exactly the right place at exactly the right time, and you have to have your telescope pointed in the right location because the shadows of solar system bodies can be moving at speeds of up to 28 kilometers (16.8 miles) per second, which

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Former KAO pilot ready for the SOFIA

ED07 0078-053 NASA Photo by Tony Landis

Bill Brockett, right, was a pilot on the Kuiper Airborne Observatory and is now flying its successor, the SOFIA. The SOFIA is currently at Dryden being prepared for a series of flights to be made with the door shielding the 17-metric-ton telescope closed. At left is SOFIA chief pilot Gordon Fullerton.

By Jay Levine
X-Press Editor

Over more than a decade, Dryden pilot Bill Brockett flew about 100 missions of the Kuiper Airborne Observatory, or KAO – the predecessor of the Stratospheric Observatory for Infrared Astronomy, or SOFIA.

When he joined the staff at Ames Research Center, Moffett Field, Calif., Brockett was not unfamiliar with the sole civilian variant of the military C-141 Starlifter aircraft that became the KAO. He had piloted Starlifters for more than 16 years in the U.S. Air Force Reserve. In fact, he flew in the reserve unit with Kuiper project pilot Terry Ragor. Brockett was involved in Kuiper missions from his arrival at Ames in 1987 until the aircraft was retired in 1995 to make way for the SOFIA.

While the main section of the Kuiper's cabin was cold and loud in flight, the flight deck was comfortable and quiet, ideal conditions for the demanding flying required for successful missions, Brockett recalled. For example, frequent heading changes – sometimes minute-to-minute – were necessary to keep the aircraft in the correct position to allow the telescope to properly track astronomical phenomena.

Good coffee was another staple for missions, which averaged seven and one-half hours and required real concentration – though that's not to say that there weren't benefits.

"I had a lot of interest in astronomy and I took advantage of being cooped up with some of the leading scientists on the frontier of astronomy work," Brockett said. "I took the opportunity to spend time with them and ask questions from my pretty basic understanding of astronomy to find out what they were doing and why they were doing it. That was a big benefit of the job."

At sundown, the aircraft would take off and it would land in the wee hours of the

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900: Meyer brings valuable KAO mission experience to his SOFIA assignment

By Jay Levine
X-Press Editor

On the Kuiper Airborne Observatory, or KAO, it was never a ho-hum day at the office for Allan Meyer.

When the "office" flies to altitudes of 40,000 feet or higher and makes flights around the world to witness astronomical events others can only imagine experiencing, it's not hard to understand why. In fact, Meyer racked up about 900 missions on the Kuiper, which was the predecessor to the Stratospheric Observatory for Infrared Astronomy.

Meyer, an employee of the Universities Space Research Association (an Ames Research Center contractor), was a staff scientist and observatory assistant for the Kuiper during much of its 21-year mission. He plans to again be part of a new day in astronomy and astrophysics aboard the SOFIA as operations associate scientist.

His job on the Kuiper – as it will be on the SOFIA – is similar to one with a ground-based telescope. Those, like Meyer, who are familiar with the instruments, telescope and measuring devices help observers get the most out of their time spent peering into the heavens. Many modern telescopes now have computer automation to direct the telescope to the right area, but Meyer's knowledge and familiarity with astronomy equipment remains invaluable.

Meyer's fellow KAO veterans and USRA employees Dave Black and Nancy McKown have also migrated to the SOFIA. Black and McKown were responsible for hands-on mechanical and computer operations on the KAO and now are heavily involved in preparing the SOFIA telescope for upcoming flight tests and initial science operations.

Meyer came to Ames in 1975 as a science data analyst, prior to joining the Kuiper Airborne Observatory team. The KAO's then-new capabilities and technologies represented a portal into an exciting world of opportunity for scientists like Meyer, who had experience working with Earth-bound observatories. The Kuiper – as in a few years will be true of the SOFIA – flew above 99 percent of the moisture in Earth's atmosphere, which obscures the infrared spectrum when viewed from a ground-based telescope.

"The KAO was dedicated to infrared astronomy," Meyer said. "That field opened very rapidly. As soon as the aircraft started flying, infrared detectors were progressing very rapidly." The first dedicated infrared orbiting observatory – the Infrared Astronomy Satellite – was not launched until 1983.

Operating the telescope was part of the job, but helping astronomers find what they were looking for was just as important.

"I was 110 percent concerned with the precise pointing of the telescope. That's one of the fundamentals of astronomy with telescopes – you have to be sure you're pointing it at the right place in the sky and make sure it stays there while scientists are using their

See Meyer, page 12

Science alliance

■ Scientists in Germany and the U.S. are seeking many of the same answers

By Jay Levine
X-Press Editor

For as long as humans have stared up into the night sky, curiosity about the heavens has drawn their gaze.

It is this fundamental need to know the unknown – and a desire for the ever-larger telescopes needed to find it – that has led Americans and Germans to forge a partnership aimed at unlocking the mysteries of the heavens.

In the Stratospheric Observatory for Infrared Astronomy, or SOFIA program, the two countries have joined to assemble the world's largest and most modern airborne observatory. Through that partnership, scientists are working toward the day when groundbreaking astronomical missions will contribute to understanding of those mysteries. And they hope to see that day come in as little as two years.

Dietmar Lilienthal, German program manager for the SOFIA, and German scientist Jürgen Wolf recently offered insights into their country's development of the flying observatory's telescope and instruments as well as what astronomers worldwide hope to discover when the SOFIA reaches full operational capabilities.

The German Aerospace Center, or DLR, is the agency leading the German portion of the SOFIA program, which accounts for about 20 percent of the program's content. The DLR contracted with German industry partners to build the observatory's 17-metric-ton telescope. German science operations, including integration of science instruments, are managed through the Deutsches SOFIA Institut, or DSI, of the Universität Stuttgart.

The German-built telescope is 2.7 meters (2.5 meters of usable surface for observation, more than eight feet) in diameter, slightly larger than the Hubble Space Telescope. The principle component, the main mirror, was built by SCHOTT Lithotec of Mainz, Germany. The mirror is constructed of Zerodur, the ceramic material used in stovetops. Use of the ceramics will prevent thermal expansion; significant temperature changes can affect the optical stability of mirrors made of other materials.

The mirror along with its stabilization system, called the primary mirror cell, weighs about two tons. The Zerodur mirror isn't the first of its type but it is one of the largest. It also is very complex. In order to reduce the telescope's weight SCHOTT staff members milled 130 holes in the rear of the main mirror, a process that did not affect its optical surface. The process created a honeycomb-like structure that reduced the mirror's weight by a factor of five from the original four-ton block of Zerodur from which it was carved.

A joint effort by German companies MT Mechatronics (formerly known as MAN Technology) and Kayser-Threde contributed optics, the bearing and the electronics for the telescope.

The mirror took two years to develop and will require further preparation before actual science missions can begin. The mirror and its stabilization system will be removed from the 747SP by crane and transported by truck to a facility located at Ames Research Center, Moffett Field, Calif. Once there, the surface of the mirror will be ground and prepared for an aluminum coating that will be added to the mirror then polished to maximize reflectivity of light from the heavens.

Dietmar Lilienthal (foreground, gesturing), German program manager for the SOFIA, points out a feature of the NASA 747SP to a group of German dignitaries, above. ***(NASA Photo ED07 0119-12 by Tom Tschida)***

SOFIA chief pilot Gordon Fullerton, center, gives a group of VIP visitors from Germany a tour of the NASA 747SP cockpit. ***(NASA Photo ED07 0119-16 by Tom Tschida)***

"It is the largest airborne infrared telescope ever built and has a mirror nine times larger than the mirror in the Kuiper Airborne Observatory's telescope and ten times higher in optical efficiency, which will allow scientists to see much fainter objects," Lilienthal said, referring to the SOFIA predecessor. The KAO was based at Ames Research Center during its 21-year career.

In addition to the telescope, German contributions will include engineers and scientists, fuel, telescope system spare parts, the SOFIA's paint scheme and the aircraft's four Pratt & Whitney JT-9D-7J engines. The Germans also are contributing two science instruments to the SOFIA's existing inventory.

German infrared astronomers in the past have collaborated with their U.S. counterparts on the Kuiper Airborne Observatory and are looking forward to future endeavors aboard the SOFIA.

"One of the highlights will include study of the galactic center, where there is a black hole," Lilienthal said. "One of the most interesting questions in astronomy is to find out what is the driving engine in spiral galaxies, and we believe that to be black holes. The better we understand black holes, the better we will understand the formation of galaxies.

"With the infrared telescope, we have the chance to use long wavelengths to peer deeply into gas dust clouds."

To support the program's science goals, the German team is relying on two additional instruments. The first, called the German Receiver for Astronomy at Tetahertz Frequencies, or GREAT, is a high-resolution heterodyne spectrometer, Wolf said, which will give readings on gas and its velocity with a greater sensitivity than ever before possible. An institutional consortium that included the Max Plank Institute for Radio Astronomy of Bonn, Germany, the Bonn University of Cologne, Germany, and the DLR developed the spectrometer.

A spectrometer is an instrument incorporated onto the telescope system to detect the energy signatures of atoms and molecules in dust clouds. Spectrometers were a hallmark of the Kuiper Airborne Observatory science and will be important on the SOFIA – five of nine instruments to be used in early missions are spectrometers.

The second is the Field-Imaging, Far-Infrared-Line Spectrometer, or FIFI LS. The FIFI LS boasts a leap in sensor technology that will enable viewing of extra-galactic, super-luminous bursts of stars. It will be used to study nearby galaxies and could provide insight into star birth and formation and the content of gas clouds like molecular hydrogen. Researchers at the Max Plank Institute for Extraterrestrial Physics in Garching, Germany, developed the instrument.

The SOFIA will offer researchers a quantum leap in capability as they explore new paths to discovery. It will be through the work of the U.S./German cooperative effort, however, that the awe and excitement of new discoveries in astronomy will be brought home to people around the globe.

A tale of two birds

Chief pilot compares the mighty NASA 747s

At top, *a NASA 747 Shuttle Carrier Aircraft departs with space shuttle Atlantis securely on top for its return to Kennedy Space Center, Fla. Atlantis landed at Edwards Air Force Base June 22 and after preparations at Dryden began its journey back to Florida.* ***(NASA Photo ED07 0137-30 by Carla Thomas) Above,*** *the NASA 747 SOFIA arrives at Dryden from Waco, Texas, where it underwent extensive modification at L-3 Communications Integrated Systems. Dryden chief SOFIA pilot Gordon Fullerton recently compared and contrasted the two types of 747 aircraft.* ***(NASA Photo ED07 0118-03 by Lori Losey)***

By Jay Levine
X-Press Editor

Gordon Fullerton knows a thing or three about specially modified 747 aircraft. That's what happens when you've been doing something for more than three decades.

Fullerton, who is the chief pilot for the NASA 747SP SOFIA – Stratospheric Observatory for Infrared Astronomy – has been piloting unusual 747 aircraft since 1983.

When the weather is not inviting at Kennedy Space Center, Fla., for a space shuttle's return to Earth, it lands at Edwards Air Force Base and requires transit back to Florida.

At Dryden, a device called the Mate/Demate Device is used to slowly lift the spacecraft onto the back of the 747 for its piggyback journey home. Fullerton is one of the NASA pilots that fly the mated shuttle/747 SCA "stack" back to Kennedy Space Center, where the orbiter is prepared for future missions.

Fullerton made the first of four check-out flights of the specially modified 747SP SOFIA on April 26. The fourth flight involved the aircraft's May 31 delivery to Dryden from L-3 Communications Integrated Systems in Waco, Texas, where it underwent major modifications that would enable it to carry a 17-meric-ton infrared telescope.

From a pilot's perspective, Fullerton said, the cockpit, aircraft layout and basic instrument setups of the two 747 models are very similar, but there are nuances in the different versions.

"There were differences that were intentional – there are two extra fuel tanks in the wings of the (Boeing SP model) because it was built for long-range flights like New York to Tokyo. The fuel panel has extra gauges to accommodate those," he explained.

Some differences are subtler.

"There are little quirky things in the cockpit that are different for no good reason, as far as I can see. I compiled a couple-page list of the little differences that I gave to Bill Brockett to watch out for – 'these things make it different,'" Fullerton said, referring to Dryden's other 747 pilot.

"Some of the more superficial things include the airspeed indicator on the SCA that has a digital Mach meter in the middle of it. For some reason, they took the same airspeed indicator in the SP and put a digital airspeed meter in the middle of it, and the Mach is separated to the side."

Both the SOFIA and the SCA aircraft are called 747s, but many of the similarities end there in terms of individual capabilities. Several enhancements were necessary to adapt the aircraft to their respective missions. Chief among these: the SOFIA 747SP carries a telescope system internally at 41,000-foot altitudes, while the NASA 747 SCA carries a 230,000-pound space shuttle on its back at 15,000-foot altitudes.

"The handling is definitely different," Fullerton said. "With the orbiter on top there is a steady rumbling vibration. …The challenge there is flying at a low speed at the low altitudes you have to, and to dodge the weather across the country to avoid precipitation that would damage the tile protection system (heat shield) on the orbiter. It's less a handling problem than a performance problem and a navigation problem. The Shuttle Carrier Aircraft also burns lots of gas, twice as much as the SOFIA will."

For the SCA flight planner, that means scheduling in a few stops for refueling. And the differences don't end there.

"The SCA has tip fins on the horizontal stabilizer – they were added to increase directional stability when you have an orbiter up there, which 'blanks out' the normal vertical stabilizer. When there is no orbiter loaded, the SCA is, maybe, over-stable – so much so that it has a crosswinds limit lower than a normal 747," he said.

The SCA stack must fly at low altitudes because of the space shuttle's tolerance for cold.

"The shuttle can handle about minus-nine degrees Centigrade. Any cooler than that and there is a risk of freezing or damaging its sensitive systems," Fullerton said.

In addition, a support aircraft always flies ahead of the stack to search for the clearest weather paths, which allow pilots to avoid potentially damaging moisture.

That is in contrast to the SOFIA flights, which will "cruise high above the water vapor and fly at a minimum of about 41,000 feet," he said. "Missions will be as long as possible – the goal for SOFIA is to fly above 41,000 feet for about six and a half hours."

During those six and a half hours, science data will be collected. Due to their length and the specificity with which the aircraft must be positioned, the biggest challenges with these flights come in developing the flight plan and obtaining the necessary clearances to fly it.

While the SCA has a single destination, in Florida, the SOFIA will be based at destinations across the globe, such as New Zealand, for its science work. Missions in Earth's southern hemisphere are valued for

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SOFIA Origins

ED07 0100-04

***Above**, the SOFIA makes its second checkout flight in Waco, Texas, prior to transport to Dryden. The received extensive modifications at L-3 Communications Integrated Systems, including installation of a pound telescope that is slightly larger than the Hubble Space Telescope. **At left**, top, the SOFIA is seen in its*

Photo courtesy Ken Rose

AC98 0012 Ames Research Center photo

ED07 0078-053 NASA Photo by Tony Landis

Visitors who attended an event unveiling the SOFIA on June 27 at Dryden enjoyed a tour of the aircraft's interior.

Photo courtesy Christina I

The Beluga Airbus aircraft delivered the SOFIA telescop

NASA Photo by Jim Ross

e aircraft 45,000- s original

configuration as a Pan American airliner that was named the Clipper Lindbergh in honor of legendary aviator Charles E. Lindbergh (see story on page three). ***At left,*** *the same aircraft is seen at Ames Research Center with a different paint scheme.*

ED07 0078-046 **NASA Photo by Tony Landis**

An L-3 Communications Integrated Systems employee continues work preparing the SOFIA for checkout flights.

ED07 0078-065 **NASA Photo by Tony Landis**

In Waco, Texas, the crew of the SOFIA prepares for the first in a series of checkout flights.

Photo courtesy L-3 Communications Integrated Systems

The SOFIA telescope is centered on the white bulkhead in the NASA 747SP's interior. Instruments will one day be mounted on the far end of the Nasmyth tube, which in this image is covered in foil.

R. Martinez/L-3 Communications Integrated Systems

e assembly safely onto U.S. soil in September 2002.

Photo courtesy Christina R. Martinez/L-3 Communications Integrated Systems

Major modifications integrating the aircraft and telescope near completion at L-3 Communications Integrated Systems.

Partners at 41,000 feet

■ SOFIA education and outreach programs help teachers and community members reap the benefits of airborne astronomy

By Dana Backman
USRA and SETI Institute
SOFIA Education and Public Outreach Director

NASA's Stratospheric Observatory for Infrared Astronomy program includes an ambitious plan to harness the unique capabilities of an airborne observatory for creating engaging national science education and public outreach activities.

The SOFIA education and public outreach plan originates with the SOFIA's predecessor, the Kuiper Airborne Observatory, or KAO, flown from 1975 until 1996. Named after scientist and astronomer Gerard P. Kuiper, an important figure in the history of airborne astronomy, the KAO carried a 36-inch-diameter (0.9-meter) telescope into the stratosphere.

Photo courtesy Dana Backman/Ames Research Center

Teachers flew aboard the KAO during its 21-year career and will take part in SOFIA missions. Above, two teachers, scientists and KAO staff at work on the observatory during a 1993 mission.

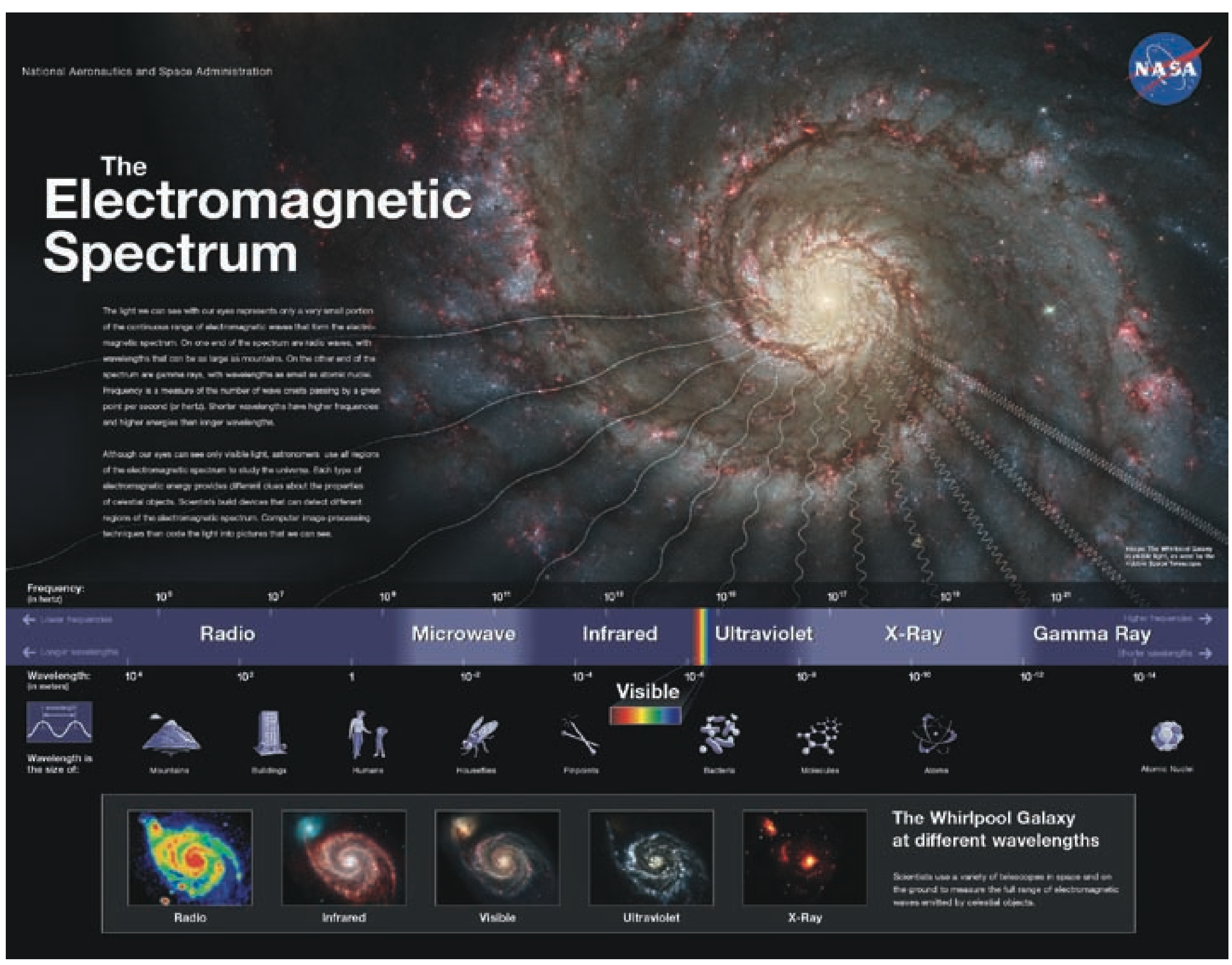

Image courtesy NASA/Space Telescope Science Institute

The front of this Electromagnetic Spectrum poster features a visual-wavelength image, taken with the Hubble Space Telescope, of the Whirlpool Galaxy (Messier 51) contrasted with a row of images of the same galaxy at a range of wavelengths from x-ray to radio. The back of the poster contained background information and suggestions for classroom activities aimed at teaching electromagnetic wave properties.

The FOSTER program

In the late 1980s officials at Ames Research Center, Moffett Field, Calif., envisioned inviting teachers on board the KAO to work with astronomers during research flights.

At the time, Larry Caroff, astrophysics branch chief; Ames astronomer Dave Koch, a frequent user of the KAO; Ames education officer Garth Hull; and KAO Mission Director Carl Gillespie began to formulate a plan focused on that goal. Koch organized the Flight Opportunities for Science Teacher EnRichment, or FOSTER, program, which was administered by Edna DeVore of the Search for Extraterrestrial Intelligence – SETI – Institute in Mountain View, Calif. About 70 teachers flew during the final five years of the KAO's mission.

Each KAO research flight was a microcosm of the scientific method. Teachers flying aboard the Kuiper obtained first-hand, real-time experiences of the scientific process: its excitement, hardships, challenges, discoveries, teamwork and educational value.

Work on board the KAO involved cooperation, teamwork and problem-solving – critical skills to pass along to students. By involving teachers in airborne astronomy research the FOSTER program enriched understanding of scientific content and processes and enabled the educators to develop insights into science-based careers. Collaboration among scientists and educators in field research pays off with re-invigorated educators who inspire students with stories of how classroom lessons translate to real life. The inspiration can be long-term, as one of the FOSTER teachers said more than 10 years after her flight on the KAO; new students coming into her middle-school classroom still ask if she's really "the NASA teacher."

John Keller and Suzanne Williams, Northern California teachers who flew on the KAO in November 1993, explained the value of their experiences in an article co-written for a publication on Ames Research Center's symposium celebrating the KAO's 20th year of operation:

"We received many very valuable lesson plans for teaching our students, including actual classroom supplies for carrying out the activities," they wrote. "We had both talked with our students about the KAO prior to our flight and had explained several lessons about infrared astronomy, meteorology, and aeronautics relating to the KAO. As the scheduled date of the flight approached, however, our students became more and more excited about the prospect of our actually flying. The morning after the flight, not only were there newspaper articles to read about our trip, but we had also produced a home video of the flight to share with our students. We spent the next two days going over the experience with our classes and using it as a teaching platform. Students were highly motivated and excited by our experience."

After his experience on the KAO, Keller pursued a Ph.D. in science education. His experience is representative of those of several FOSTER alumni who responded to a survey 10 years after participation in the program and said they found the program a career-altering experience. Teachers reported that the program inspired them, with some becoming state science teaching coordinators, state teachers of the year and Presidential Outstanding Teacher honorees.

Airborne Astronomy Ambassadors

The Airborne Astronomy Ambassadors program, through which educators will fly on the SOFIA, was modeled on the KAO FOSTER program. It is the SOFIA's flagship education and public outreach initiative. Once routine scientific observations are begun by astronomers on the aircraft, up to 100 guests will be selected each year to participate in one or more research flights. Those who might qualify for the program include classroom teachers, science museum and planetarium staff as well as, potentially, avid amateur astronomers affiliated with public outreach programs.

Proposals will be solicited from teams of educators across the United States. Submitters will be required to describe plans to promote science education in their home communities by making use of their SOFIA training and flight experience.

Astronomers who submit research proposals for the SOFIA in the ambassadors program will specify whether they want to work and fly with an educator team. During the FOSTER program, a majority of astronomers took advantage of the opportunity to work with teachers on the Kuiper.

After selection, educators will undergo a six-month training period, including an

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AC 42233-6 NASA Photo courtesy Lynn Albaugh/Ames Research Center

AC92 0437-3 NASA Photo courtesy Lynn Albaugh/Ames Research Center

ED07 0140-53 NASA Photo by Tony Landis

***At far left** is the CV-990, an early NASA airborne observatory also known as the Galileo I.*

***Above**, the Learjet was the first dedicated platform for airborne astronomy.*

*Senior Ames astrophysicist Ed Erickson, **at left,** has been a key figure in the field of airborne astronomy.*

History Lesson ... from page 3

Low's telescope also incorporated a clever device that suppressed noise due to fluctuating infrared radiation emitted by the atmosphere.

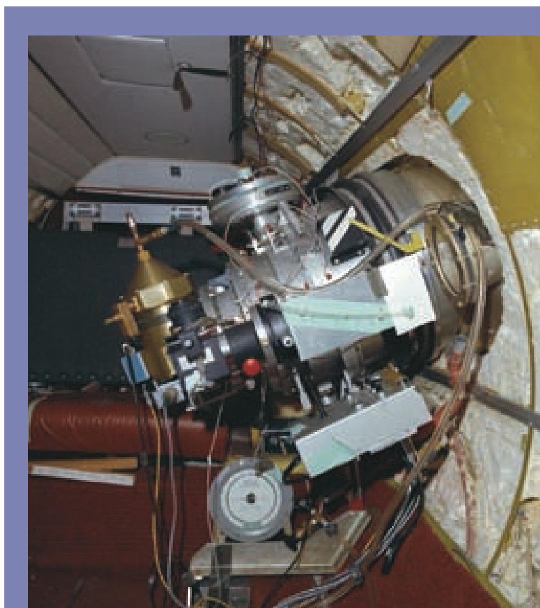
"The flights were about two and a half hours long and the Learjet would ascend directly to 45,000 feet," he said. "At that altitude the infrared spectrum opened up and we were able to make measurements – more or less routinely – in the far infrared. Low's telescope was a remarkable device, but a number of refinements and considerable documentation were needed to improve performance and user friendliness," so Erickson and a team of Ames engineers built an improved version of the telescope in the early 1970s.

"Our Learjet telescope became pretty popular; we had about six groups from around the country come use it. The Learjet was used for other research besides astronomy, but we could remove and install the telescope very quickly. People would bring different instruments and put them on the telescope," he said.

Was it time to answer the question about Venus' atmosphere? If it wasn't water in the atmosphere, what was it and why did it appear to have a yellowish tint?

"We measured the spectrum of Venus in a slightly longer wavelength range – still in the near infrared. The spectrum is complicated. It's largely reflected sunlight at that wavelength, but it's affected by the composition of the atmospheric aerosols. You're getting into the part of the spectrum where you're seeing some emitted radiation, and that's a different process. Any body at any temperature is emitting radiation. So there's a crossover between reflected light from a planetary object and emitted light as you go to longer wavelengths," Erickson explained.

The answer was there, but it required the late Jim Pollack, an Ames astrophysicist and senior space research scientist, to find it. If Pollack's name rings a bell, it might be because of his work on planetary atmospheres – he was the scientist who developed the theory of a "nuclear winter" in the event of atomic war.



Following Ames Research Center's success using a small telescope in a CV-990, this 12-inch infrared telescope at left was mounted in a Learjet. Research conducted with the Learjet, the first dedicated airborne observatory, paved the way for expanded efforts with the Kuiper Airborne Observatory. As the next-generation airborne observatory, work with the SOFIA is expected to begin in about two years.

NASA Photo AC92 0437-3 courtesy Lynn Albaugh/ Ames Research Center

"Pollack's aerosol models, when compared with the spectrum that we measured from the Learjet, indicated that the clouds of Venus were made of sulfuric acid – very concentrated droplets. Another group with a different technique concluded the same thing," said Erickson.

The Learjet continued to be a valuable tool for connecting researchers with exciting discoveries, such as the ability to measure far-infrared emission from molecular clouds.

"Molecular clouds are the most massive objects we know of in our galaxy except for the black hole at the center. That's where stars form. They (molecular clouds) are opaque because of the little, tiny dust particles within them. The luminosities of these clouds (revealed in the far infrared) and the shape of the spectrum tell you something about the heating sources inside and about the structure of the cloud," he said.

The aircraft offered researchers a continual journey into discovery.

"The Learjet was exciting to fly because you had to find all the targets yourself through a visual guiding telescope, a little three-inch telescope. The challenge was to find the star field. The pilot would say, 'O.K. we're on heading; you can look now.' If you were in a relatively straightforward constellation where you could find the star or the object you wanted, that was fine. However, sometimes it was difficult to see exactly when you were in the right place," Erickson said.

The Learjet science mission was a success, but researchers wanted a larger, more advanced telescope that would provide them with an even more effective tool for finding answers to other questions in the field of astronomy.

Kuiper Airborne Observatory

In the 1960s and early 1970s, work with the CV-990 and Learjet had reinforced the value of a dedicated airborne observatory. Ames staff successfully advocated for and developed with contractors a new observatory, one featuring a 36-inch telescope mounted in a civilian variant of the Lockheed C-141 Starlifter, a four-engine jet transport.

In the world of scientific research, however, plans rarely go off as expected and efforts to get the new flying observatory into the skies were no exception. Parts for the aircraft were delivered to Ames in 1973, where the telescope was assembled and installed. But as the project was nearing flight readiness, Gerard Kuiper, a pioneer in modern planetary science and one of a very few professional astronomers to study the planets during the 1940s and 1950s, died unexpectedly on Christmas Day 1973.

When the airborne observatory began its full operational capabilities in 1975, it did so as the Kuiper Airborne Observatory, or KAO. It was a fitting tribute to one of the scientists responsible for opening up the field with his work on the CV-990. The Dutch-American astronomer was a pioneer in applying the techniques of astrophysics to the study of planets and moons in the Milky Way and suggested that airborne astronomy would provide knowledge of the universe obtainable by no other means.

The KAO telescope was three times the diameter of the Learjet telescope, collecting nine times as much light during an observation. The new aircraft's capabilities meant longer observations and a larger support staff, enabling dramatically more sophisticated and sensitive observations. The KAO was based at Ames during its 21-year career. One thousand, four hundred and sixty-three research flights of about seven and one-half hours each were made with the aircraft, an average of about 70 flights per year.

Scientific instruments are the source of data produced at any observatory. The Kuiper staff fostered an environment of discovery using more than 40 science instruments through which a wide variety of technologies were developed, installed and operated in flight by science teams from university, government and corporate laboratories, both U.S. and foreign.

The Kuiper infrared telescope's resolution and stability allowed researchers to notch a number of firsts. It was used to determine that water existed on Jupiter, to discover the hidden stellar content and structure of galaxies, to peer inside molecular clouds and to identify a wealth of information about the density and composition of gases in those clouds, revealing clues about star birth.

"It was an exciting time, because anything you could measure at these longer wavelengths was brand new," Erickson concluded.

Meyer ... from page 5

equipment, making measurements and getting what they want," he explained.

He also had to be a quick study of the Kuiper's other features, such as conditions on board the noisy aircraft.

"Scientists would put food on the floor (of the aircraft) and forget about it. When they would return, it would be frozen. I learned to wear thermals and a flight suit. It was warmer elsewhere in the cabin, but it was coldest next to the telescope."

Adjusting to the Kuiper's onboard environment was easier than trying to find invisible objects in the sky. "Viewing" objects in the infrared, he explained, is difficult because scientists often can't actually see what they're looking at and must wait until data captured by instruments recording information in the infrared spectrum are analyzed to provide conclusions.

"In the first year or two, scientists would go after the things that were easy because they hadn't been done. By 'easy,' I mean bright and easy to detect and measure – things that were already known, or were expected to be easy to do, like planets, the center of the galaxy and some unusual stars," he said.

Then researchers "tuned up" their instruments and began going after fainter objects, like distant galaxies. If scientists came in the spring, they would be back in the fall and go after objects 10 or 100 times fainter than those they'd observed earlier in the year, in the process pushing the KAO technology to the limits of its capabilities.

"It's exciting to be a part of something where just about every time you go to do it, you're getting positive and interesting results. A lot of science traditionally involves negative results. It's not really an experiment if you routinely get positive results, or expected results. In this case, people were coming back saying, 'We got this, we got that. We found that flux. We got the energy of the quasar.' We were seeing the universe in a new way for the first time.

"It was an era of discovery."

Missions were flown on an average of two nights per week and the increasingly fainter subjects required more complex mission preparation.

"You can't just go on a fishing expedition over the whole sky," Meyer noted.

To allow scientists to focus on their research objective, Meyer became a sleuth. He scoured the biggest collection of images of the sky – the whole sky. The collection included about 2,000 wide-angle images captured from California's Palomar Observatory through a 1949-1957 National Geographic survey of the northern sky.

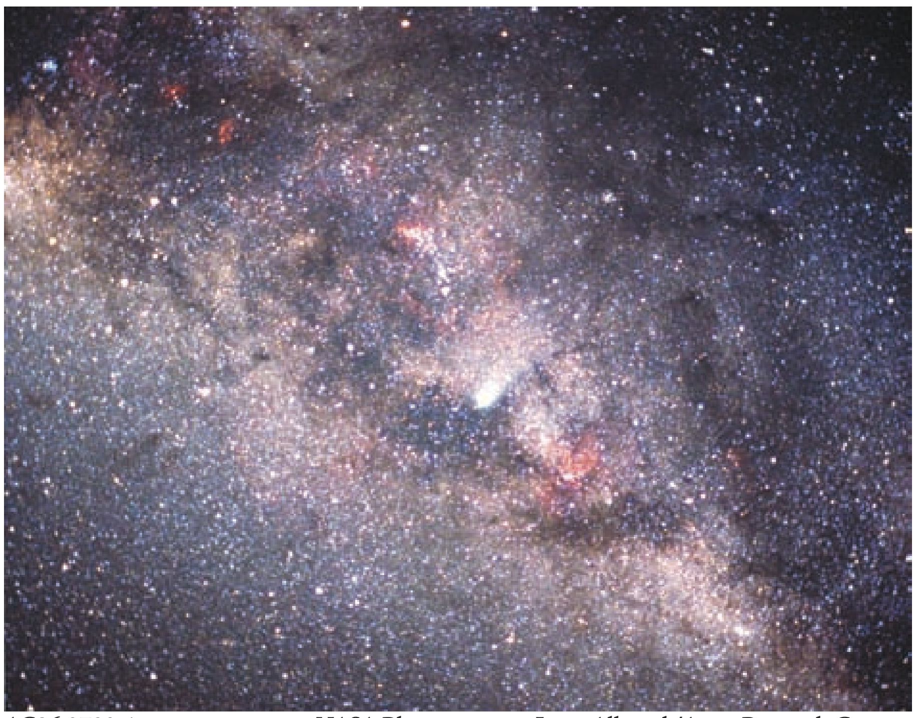
He then cross-referenced the Palomar study images with information from available star catalogs, searching in the neighborhood of the research object, and develop custom maps for the mission. Such an effort sometimes takes more than 80 hours to complete for a flight. In addition, he used maps of radio emissions, developed from ground-based observatories, which could be used like topographical maps to find celestial coordinates of possible "hot spots" – that's where the KAO would go hunting, he said. Scientists' hypotheses would provide other clues for where to find infrared hot spots.

Overlapping the optical photographs and star coordinates from the star catalogs, Meyer helped scientists use the KAO to bridge large, sparse gaps between catalogued stars in the search for objects in the infrared spectrum. Larger star catalogues, which did not become available until the 15-million-star Hubble Guide Star Catalog of the 1980s, gave Meyer a big assist.

Thanks to Meyer's preparations, within a few minutes scientists could find the object they were seeking once the aircraft was in position to "see" it.

AC94 0350-3-3 NASA Photo courtesy Lynn Albaugh and Allan Meyer/Ames Research Center

Above, *Allan Meyer works at his station on this July 22, 1994, Kuiper Airborne Observatory mission based in Melbourne, Australia, and focused on viewing the impact of the Shoemaker-Levy 9 Comet's impact on Jupiter.* ***Below,*** *the KAO telescope captured this image of Halley's Comet streaking across the Milky Way galaxy during a New Zealand-based mission on April 6-7, 1986.*



AC86 0720-1 NASA Photo courtesy Lynn Albaugh/Ames Research Center

"It's not like street names on corners with block after block. There were places in the skies that were interesting almost right away, where there were these gigantic clouds of dust in space that are light years across and very thin. You can't see any stars and if you look at a photo, it's just a big black spot in the sky. There are no stars at all. How do you find your way?"

The answer is simple: continue studying the sky.

"We did some of the earliest investigations to find warm spots radiating in the infrared within these dust clouds that we now are pretty certain are where stars are forming. Condensations are forming and heating up and becoming stars," he added.

His work with the KAO was an experience Meyer valued highly.

"It's really hard to pick out a single flight, a single result or a single experience and say 'that stands out,' because for me it was the whole experience that, all together, represents something I'm very grateful to have been a part of."

Having said that, what Meyer termed one of the Kuiper's most intense missions took place in 1987.

"The most dramatic example…was when the supernova went off. Fortunately, we had started organizing the logistics for a southern skies expedition anyway. When the supernova went off, in a couple of weeks it became a much more ambitious expedition to go after something that hadn't happened in our sky for hundreds of years."

Designated SN 1987A, the event occurred in a small dwarf galaxy called the Large Magellanic Cloud. Two Magellanic clouds, a large and a small one, first were noticed with the naked eye during Portuguese explorer Ferdinand Magellan's sixteenth century journey around the globe. The dwarf galaxies orbit the Milky Way about 150,000 light years away, and the radiation and light from the supernova had just reached Earth in 1987.

"Supernovas are known to be a catastrophic, totally destructive explosion of a star that has become unstable. It's impossible – words fail almost any astronomer who tries to describe what we're talking about here: The normal, steady-state power output of the sun is equivalent to several billion hydrogen bombs going off every second. The sun is a stable star – imagine something bigger than the sun destroying itself in an explosion," he said.

There was another adventure when infrared examinations of Halley's comet in the southern sky kept the KAO active with dozens of dedicated flights between fall 1985 and late spring of 1986, when the comet came closest to Earth. The Kuiper and its crew were deployed to New Zealand for three months.

"Our claim to fame was that we were able – by flying above the moisture in Earth's atmosphere – to directly measure the predicted dominant constituent as water. Comets always were hypothesized to consist of, basically, frozen water and some contamination such as interplanetary dust that got mixed in when it formed. But because of the moisture in our atmosphere, ground-based observatories could not directly observe the water signature," he said.

"It was not a surprise, but it was good to quantify it and take measurements."

Another comet in deep space, the 1994 Shoemaker-Levy comet, was captured by Jupiter's gravitational field and hit the planet. The KAO and its crew were dispatched, flying a fast-paced flight series to study the multiple impacts and their aftermath.

"If you're looking for the most challenging mission, this could be it. We had about a one-week time span for flights with three or four different instruments. Even if we had been based at Ames for the start of the missions it would have pushed the KAO's capability. As it was, we were based at the Melbourne, Australia, airport for the Shoemaker-Levy comet missions. The comet hit (Jupiter) like a shotgun blast – or, more like a machine gun. Each night another piece of comet would hit the planet," Meyer recalled.

"We viewed the impact site for hours as the aircraft traveled all across Australia. We saw thousands of tons of superheated water and methane gas blowing out into space and showing up as extremely bright emission lines in the infrared spectrum. We were watching explosions on the scale of the size of the Earth right before our eyes."

Meyer expects to bring those experiences to bear in his work with the SOFIA, and looks forward to a new series of ground-breaking discoveries in astronomy.

Brockett ... from page 5

morning. Missions would keep the Kuiper on a straight heading for legs that ranged from as few as 12 to 15 minutes each to 45-to-60-minute stretches, depending on the sensors the principal investigator used and the celestial object being sought. Often, even the scientists on board didn't know whether a flight was successful until the data were later analyzed.

Flight planners resolved complex issues to determine the conditions at which a scientist would be able to "see" what he or she was looking for, arranging the flight to maximize the time spent viewing that object. The intense preparation meant as much as half of a flight could be dedicated to the primary science goal.

Another challenge was coordinating with air traffic controllers for clearances along the route. The navigators were primarily responsible for the meticulous work of assembling a flight plan. Among the KAO's three navigators was Bob Morrison, who previously had served as a B-17 navigator during World War II and retired along with the Kuiper in 1995.

The biggest challenge for a pilot, Brockett said, was making the call about what to do when things didn't go as planned. It was the pilot who would decide whether the mission should be abandoned, or if there was a way – safely – to make everything work out. One example that illuminates such a situation involved a mission in which researchers wanted to view an anticipated occultation of Pluto to determine whether the planet had an atmosphere.

At 4 p.m. on mission day, the KAO's fuel tanks were filled for a 10-and-one-half-hour mission that had been in planning stages for more than two years. Thermal expansion caused the wing to vent, and fuel began to puddle on the tarmac.

The crew resolved the problem and stopped the venting, but the incident caused delays. After coordinating with the fire department – always alerted when fuel leaks occur, to clean up the potential hazard – the aircraft was soon ready to depart without having to shut down all the scientists' instrumentation.

But the mechanical difficulties were not fully resolved. During a checklist review of the plane and its systems prior to takeoff, a malfunction was discovered in an auxiliary power unit that enabled the hydraulics to work if the aircraft was on the ground for prolonged periods.

"The units are to be shut down for flight, but the (malfunctioning) unit kept restarting when technicians on the ground would turn it off," Brockett said. "We discovered we could turn the rogue unit on and off by using the aircraft's circuit breakers. We decided to go on with the mission."

Strong headwinds threatened to keep the aircraft from making up the eight minutes that had been lost on the ground, and tension mounted. Getting to the area to view the occultation was critical and eight minutes might have meant the loss of a rare opportunity.

"An occultation is when a planet passes in front of a star, and it's a great opportunity to analyze the starlight before the planet gets close to it and as the planet passes," he explained.

"There was a very specific objective. This mission was not aimed at collecting buckets of data to be analyzed over a period of years after the mission. It was expected we were going to make a discovery.

"It's hard to think of a planet that is so far away and so dim you can't even see it as a shadow. But that's what it is, and the shadow is moving very fast and it's big – it's like an eclipse, only it's moving a lot faster. Observations made viewing the occultation proved Pluto had an atmosphere."

Brockett and SOFIA chief pilot Gordon Fullerton flew the latest airborne observatory from Waco, Texas, to Dryden in June, where the aircraft is being readied for its eventual mission. The SOFIA will help researchers continue the Kuiper mission. Brockett said he looks forward to helping open the next chapter in airborne astronomy.

Education ... from page 10

online course, before their flights. During this time SOFIA education and public outreach staff will keep educators in contact with their astronomer partners. Training and pre-flight contact with their astronomer partners will acquaint educators with the goals of scientific experiments planned by astronomers using the SOFIA. The educator teams will then be brought to Dryden Flight Research Center for orientation before a flight series – two to three flights over the span of about a week – with their astronomer partners.

Educators will take back to their schools and communities the sum of their experiences. With ongoing support from the SOFIA education and public outreach program, they will implement the enrichment plans in their original proposals. Flying on the SOFIA is intended to be the beginning, not the end, of the educators' relationship with NASA and the SOFIA.

Maureen Savage, who will be a SOFIA scientist, sets up a model outdoor solar system with an elementary school class. The Earth Partners program seeks to pair educators with scientists and engineers. SOFIA researchers will commit to a series of classroom visits in which they will share results of their work.

Photo courtesy Astronomical Society of the Pacific

Vision for education, public outreach

In the early 1990s Larry Caroff left Ames for NASA Headquarters, where he co-authored formal requirements to begin the process of replacing the aging KAO. As part of those requirements, developers and operators of the SOFIA also needed a plan to use the observatory's unique capacity for education and public outreach, including having educators on board during research flights.

Universities Space Research Association, a non-profit consortium of space research institutes and universities, was chosen to fill that role. Managers and participants from the FOSTER program wrote the education and public outreach portion of the USRA proposal.

The USRA plan for development and operations of the SOFIA detailed an extensive program with many components. The USRA subcontracted the SOFIA education and public outreach work to the SASP alliance, a partnership between the private SETI Institute and the Astronomical Society of the Pacific, institutions with broad experience connecting researchers with educators as well as in public and astronomy education and outreach.

While the ambassadors program is the key program to result from the alliance's efforts, five other plans also were developed, including the Earth Partners program; Active Astronomy classroom demonstration kits; an astronomy graduate course for teachers; the Yerkes program for students with visual handicaps; and providing tools of knowledge for a multitude of NASA programs.

Some astronomer research teams will prefer to mentor and work with educators and students in their local areas without partnered flights aboard the flying observatory. In the Earth Partners program scientists and engineers will be matched with local educators and trained to work together and the teams then will commit to a series of classroom visits.

The Active Astronomy kits developed by SOFIA education and public outreach staff will comprise four activities that focus on improving student understanding of infrared light. These hands-on and demonstration activities are designed to supplement instruction on the electromagnetic spectrum for middle and high school students.

Providing an online astronomy graduate course for teachers is another targeted goal and that goal will be met with "The Invisible Universe Online: The Search for Astronomical Origins for Teachers."

The course, administered through Montana State University, presents scientists' search for astronomical origins through the use of multi-wavelength astronomy. Course materials describe how astronomers use all energies of light to unwrap the secrets of the universe. Homework activities and discussions focus on how to teach and demonstrate course concepts to middle and high school students. Course content is aligned with the goals and emphasis of National Science Education Standards.

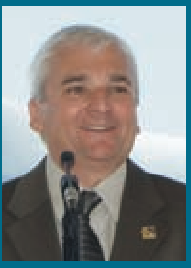
At the University of Chicago's Yerkes Observatory in Williams Bay, Wis., engineers and scientists are constructing the SOFIA's far-infrared camera called the High-resolution Airborne Widebandwidth Camera, or HAWC. The Yerkes education and public outreach program, supported in part through the SOFIA program, has developed and implemented a summer curriculum of astronomy and other science instruction for students who are blind or have visual handicaps.

Tools of knowledge

SOFIA education and public outreach programs contribute to NASA's evolving Origins/Structure and Evolution of the Universe programs. One example of progress is a poster about the electromagnetic spectrum that was included in issues of national science teacher magazines in the fall of 2003 with an accompanying article co-authored by Denise Smith of the Space Telescope Science Institute, Baltimore, Md., and the SETI Institute's DeVore.

Learning should be exciting, and the SOFIA education and public outreach program is structured to get teachers – and by extension, their students – on board for awe-inspiring flights of discovery leading to better understanding of the heavens.

Notable & Quoteable



"SOFIA will join the ranks of the great observatories and give the world a much different view of the universe, one filled with discoveries that will inspire us all."

– Kevin L. Petersen, Dryden Center Director

"This is an international partnership. We've been working very hard, between NASA and our German partners, DLR. This is a template for many great things to come."

– Peter Worden, Ames Center Director

"In about two years we expect to start making scientific observations with this new observatory ... that are difficult, if not impossible, to achieve from space-based satellites."

– Richard Howard, Deputy Director, NASA Astrophysics division

"Together with our colleagues from the United States and Germany we are patiently awaiting the first flight opportunity. ... All indications give rise to the hope that this day is coming closer and closer."

– Werner Klinkmann, DLR Deputy Head of Space Science

Kuiper Observatory ... from page 5

is the orbital speed of the Earth around the sun," explained Ed Erickson, senior astrophysicist at Ames Research Center, Moffett Field, Calif., who worked with Elliot on a later occultation observation from the KAO. "They were measuring the starlight as Uranus was heading to pass in front of it, and all of a sudden the starlight dimmed to practically nothing.

"Elliot's team thought the instrument was broken. Then the starlight brightened again. Then it dimmed, it brightened, it dimmed, it brightened. Then the planet went in front of the star and so they decided to extend the flight leg and look at the starlight after the star had reappeared from behind the planet. Sure enough, they observed the same phenomenon – the starlight was undulating, it would go up and down and up and down."

The researchers soon had an explanation for the mysterious behavior. "What this was," Erickson said, "was the nine rings of Uranus."

The Kuiper Airborne Observatory enabled that discovery. The KAO was the first fully dedicated infrared airborne observatory and the immediate predecessor to the Stratospheric Observatory for Infrared Astronomy. Over 21 years, the KAO flew more than 1,400 flights, ending its career when the aircraft was retired in 1995 to enable construction of the SOFIA.

Named after Gerard P. Kuiper, recognized for his contributions to the field of solar system astronomy and one of a very few scientists studying planets during the 1940s and 1950s, the KAO was a key conduit in astronomers' quest for scientific discovery. Discoveries on the Kuiper were many and varied, but included finding water in Jupiter's thick atmosphere and groundbreaking work on star birth and death alike through analysis of supernovas.

The Kuiper's solar occultation observations epitomize the advantages of mobility that an airborne observatory provides.

"When there's a solar eclipse it doesn't occur in all parts of the world," Erickson explained. "It occurs in certain places because of the [Earth/sun/moon] geometry. These are ephemeral – short-lived – events and you have to observe them from a particular place at a particular time. So mobility is one of the great attributes of airborne astronomy and it's a unique capability. There is no other facility – no spacecraft, no ground-based telescope, no balloon; only airplanes can do this."

Another unique hallmark of the KAO was the access it provided to nearly the entire infrared spectrum. With the airborne observatory, outstanding contributions were made to understanding the birth of stars and other processes in the interstellar medium – the space between stars. KAO researchers, for example, found embryonic stars hidden inside dense dust clouds and evidence of a massive black hole at the center of the Milky Way galaxy.

Most of Erickson's research has involved infrared instrument development for, and observations from, the Ames-based Kuiper and one of its predecessors, a specially outfitted Learjet. His research has included infrared measurements and interpretation of a variety of objects in the solar system and interstellar medium.

The KAO featured a 36-inch reflecting telescope as well as several new and evolving astronomical instruments. Availability of the airborne observatory, Erickson said, enabled researchers to develop and exploit advances in optics, cryogenic instrumentation, infrared detectors, computers and data systems that will benefit the next-generation airborne observatory, the SOFIA. The SOFIA's more technologically sophisticated instruments will offer significant advancements over those of the legendary Kuiper.

Erickson made many key contributions to research aboard the Kuiper that provided him with a foundation to draw on in maximizing SOFIA mission capabilities. He was an early advocate of the SOFIA in the 1980s and developed initial contacts with German scientists on the potential for a SOFIA collaboration, he led the SOFIA Science Working Group and organized a SOFIA Technology Workshop at Ames in 1996.

Also to Erickson's credit are recommendations for improving the telescope's optical configuration, to minimize performance-degrading backgrounds that radiate on detectors; installation of the telescope behind the wing to reduce cost; and for development of science instrument interfaces for the telescope.

He is the primary author of the SOFIA's initial science requirements and was the original SOFIA project scientist for NASA from 1997 to 2001 before serving a three-year stint as SOFIA facility scientist. Erickson monitored development of the telescope optics at every major review, participated in telescope progress reviews and also developed a rugged secondary mirror for the telescope.

Erickson explained elements of the Kuiper's legacy, which were highlighted at Ames airborne astronomy symposia in 1984 and 1994.

"KAO investigators measured the luminosity of Jupiter, Saturn, Uranus and Neptune; all but Uranus were found to have internal heat sources, which means they emit more light than they receive from the sun," he said. "These are of great interest in understanding the formation of these planets and their internal composition and structure."

Finding water in Jupiter's atmosphere with infrared instruments was another first for the Kuiper.

"You cannot detect water from ground-based facilities in the infrared because the Earth's atmosphere blocks those wavelengths. (Finding) water on Jupiter was exciting because it allows a variety of different chemistry in Jupiter's atmosphere and the possibility of some peculiar lifelike entities that people have speculated on since this discovery," Erickson said.

Another interesting find was in explorations of a major new component – photo dissociation regions – of the interstellar medium.

"We knew there were molecular clouds and we knew there were stars, but at the edges of molecular clouds there is neutral atomic gas, which had only been speculated about. It was explored with spectroscopy from the KAO; it's a major constituent of the interstellar medium," he said.

Spectrometers, key instruments used in the Kuiper's work, will play a major role in the science gathered with the SOFIA. In fact, five of nine instruments intended for use on the SOFIA during its first missions are spectrometers. Each instrument is mounted on the telescope to receive the radiation it collects.

"We did a lot of spectroscopy – looking at the features of reflected and emitted and absorbed radiation, which occurs at particular wavelengths or colors characterizing the different atomic and molecular species. We know that the universe is made up of the same elements we have on Earth because all of these – every type of atom and molecule – has its own particular set of wavelengths," he said.

"(Spectrometers) separate the color of light, allowing researchers to analyze the features of the spectrum. That enables determination of the composition of solids and gases in space, as well as gas properties such as density, pressure, temperature and velocity.

"For example, the infrared light from solids, such as interstellar grains, is the heat they radiate into space, but the shape of their spectra reveals their composition."

Astronomers harnessed the KAO's capabilities to study a wide variety of objects.

"Objects called 'Bok Globules' (named for Harvard astronomer Bart Jan Bok) appear to be dark spots in the sky; they used to be thought of as 'holes in the sky.' Later they were found to be cold, dark clouds – smallish, and thought to have no activity in them. From the Kuiper in the far infrared, you could actually see that there were luminous spots in these things where stars were formed inside. That was a real revelation in star formation."

It wasn't the first breakthrough the Kuiper helped identify, nor would it be the last.

"By measuring the infrared radiation from galaxies it was found that typical spiral galaxies like our own emitted as much energy in the far infrared as they do in the visible. That's really a revelation because it tells you previous estimates of the luminosity were wrong. It tells you about the interstellar content, and that's fundamental to the structures of galaxies," Erickson said.

In 1987 astronomers found an erupting supernova 150,000 light years away from Earth in a nearby galaxy called the Large Magellanic Cloud. Astronomers tagged the event SN1987A.

"People speculated heavy elements were formed in supernova explosions. Stellar burning stops at iron, and beyond that you're not going to get much heavy-element production in ordinary stars. This rapid production of the heavier elements in the explosive process of a supernova had not been confirmed, but we did that from the Kuiper and with ground-based telescopes. We saw and measured infrared spectral lines from iron, cobalt, and nickel and argon that had formed in the blast," he said.

Still another example of how the Kuiper's capabilities enabled new discovery was evident in the study of Jupiter's atmosphere. Earlier attempts, with the Learjet, to find ammonia were fruitless. In fact, some scientists were beginning to doubt whether ammonia was present because it wasn't easily detected. The far-infrared spectrum measured on some of the earliest KAO flights revealed ammonia absorption bands and led to a refined model of the Jovian atmosphere.

"The (telescope) pointing system was much more sophisticated (on the Kuiper compared with that of its predecessors) and you didn't have to guide the telescope yourself. The KAO had staff on board who would (locate) the star field and point (the telescope) to the desired object. Many of the objects were invisible, even though they might be bright in infrared wavelengths," Erickson said.

The KAO produced valuable research right up through its last flights.

"In the last year of the program we looked at an emission-line star called MWC-349. We knew from earlier measurements we'd made that it had a disk around it. A theorist predicted the disk could produce far-infrared laser-line emission that could be detected from the KAO. We measured this on our last KAO flight, in 1995.

"It was exciting because nobody had seen such a thing. That's how a lot of these highlights are – totally unexpected when the facility or instrument is conceived. And for SOFIA, astronomers will surely observe phenomena we haven't dreamt of," Erickson said.

"In every generation there are people whose curiosity instinctively drives them to extend the limits of perception. Airborne astronomy provides such opportunities. It's an exciting endeavor, and both the unique science and the unique hands-on experience tend to be addicting."

Lindbergh ... from page 3

dedicating it, is that it represents that man in most of his life," Lindbergh said.

Erik Lindbergh has inspired many with his own adventure reenacting his grandfather's historic transatlantic flight from New York to Paris. His reenactment flight was made in 2002, 75 years after his grandfather's original journey in 1927.

As the crowd at Dryden counted down from 10, Lindbergh climbed stairs leading to the aircraft's fuselage and pulled a red, white and blue banner off to reveal the name "Clipper Lindbergh."

His grandfather had been a thinker, Lindbergh noted, a man who in addition to his flying achievements tried to "solve the great riddles of his time" and considered not merely emerging technologies but the ramifications inherent in them. The inspiration created by the 1927 flight, Lindbergh said, is mirrored in the SOFIA 747SP aircraft.

Outreach elements planned as part of the SOFIA program, including the possibility of educators traveling with program scientists, serve as examples of what is needed to inspire a new generation of scientists and explorers, he said.

"This is an age of tremendous apathy, when we have all kinds of threats facing us. Not just wars, but global warming and environmental threats," Lindbergh said. "We don't feel like we can affect the outcome. We can switch bulbs, or buy a hybrid [vehicle], but will that really do anything?"

Answers, he emphasized, lie in education and renewed commitment to discovery.

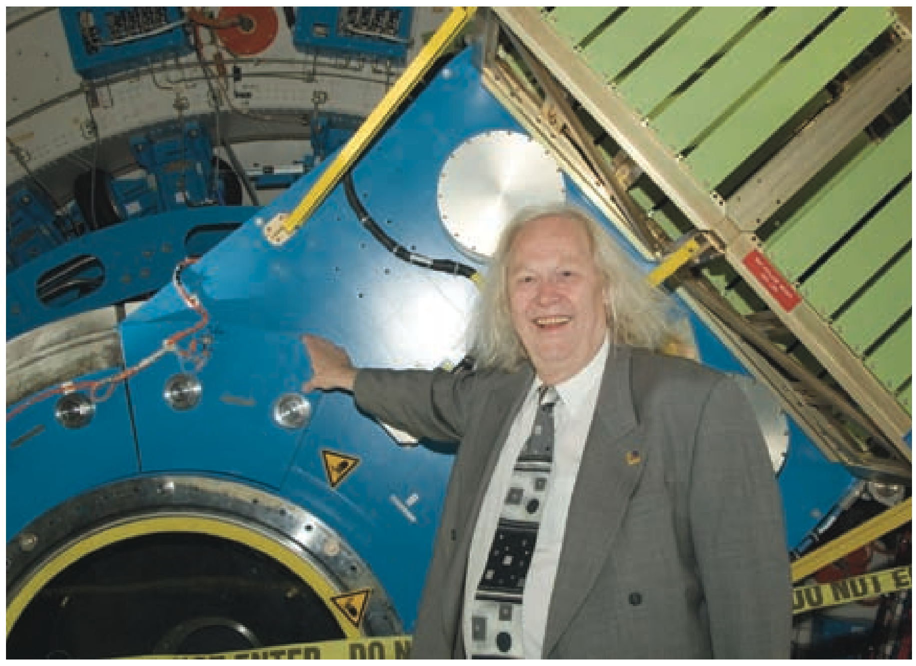
"The only way that is going to change is through education." Gesturing toward the SOFIA, he said, "This is going to be an extraordinary platform for that education, one that will hopefully ignite one of those people who is touched by this program that will enable the breakthroughs we need – that our children need, that out children's children need to thrive and survive into the future. I truly believe that we are but in our infancy in terms of expanding and exploring human potential.

"[The SOFIA] represents a fantastic step, one that I hope will bring us to that future."

Flown at altitudes above 40,000 feet, the SOFIA's infrared telescope will be above nearly 99 percent of the Earth's atmospheric water vapor, greatly enhancing existing capabilities for studying the cosmos. The state-of-the-art telescope also will allow greater flexibility and ease of instrumentation upgrade than are possible with satellite-borne observatories.

NASA's partner in the SOFIA program is the German Aerospace Center, which provided the telescope. A 16-foot-high opening cut into the plane's aft fuselage will allow observations with the telescope to be made at altitude.

Science ... from page 4



ED07 0140-04 NASA Photo by Tony Landis

SOFIA chief scientist Eric Becklin is a pioneer in the field of infrared astronomy. He's ready to continue his work when the flying observatory is ramped up for science missions during the next two years. While the Kuiper Airborne Observatory revolutionized the field of infrared astronomy, the SOFIA's larger telescope and latest instrument upgrades will help scientists delve deeper into mysteries of the universe such as star birth and death.

Gerry Neugenbauer, he discovered in 1966. Their discovery is known as the Becklin-Neugenbauer Object. Becklin also served as the first director of the NASA Infrared Telescope Facility at Mauna Kea, Hawaii.

Becklin's experiences make him a good fit for the job of SOFIA chief scientist. In his newest role he said he looks forward to using the SOFIA's new and seasoned instruments, which will make it much easier to detect differences along the electromagnetic spectrum.

"We can split up the light with a spectrometer that … allows you to look in detail at what's in the spectrum. Then you start seeing lines due to the atoms and molecules that are out in space. We can study in much greater detail the chemistry out in space and even the biology. Potentially, we have the ability to see some organic signatures that would indicate if life is forming out there," he said.

A spectrometer is an instrument incorporated into the SOFIA telescope system to detect and divide heat radiation from space. Spectrometers were a hallmark of the Kuiper Airborne Observatory science and will be important on the SOFIA – five of nine instruments intended for use on early missions are spectrometers. It's a tool with which Becklin is well acquainted and one he continues to use to study space molecules and failed stars like brown dwarfs.

"Science is the progress of always doing things better by looking fainter, or deeper into the universe, with greater clarity, or with greater spectral resolution that allows you to separate more molecules and atoms," he said.

The SOFIA's mobility also gives it some big advantages over space-based telescopes.

"There are certain astronomical observations and events that happen in only certain places on the Earth," he said. "An example of that is an eclipse of the sun. You can study eclipses, and there are similar events called planetary occultations [through which] you can study planets. So you can study the sun or moon in a solar eclipse and you can study the planets in a planetary occultation. They happen in only certain spots on the Earth." The SOFIA's mobility, he said, will allow astronomers to dispatch it to strategic locations for observing such events.

The capability of returning to a home base is another plus, because it allows researchers to take risks that would be cost-prohibitive with technology on a space-based telescope.

"We come home every night and we can put on the latest and greatest instrumentation," he noted.

"Because we're on an airplane platform, we can fly big instruments and quite complicated instruments that you really wouldn't want to put into space. We also have the potential to fix problems. In the space program, some problems put you down completely. We will always be continually improving, modifying and fixing any problems we have with the aircraft, telescope and instrumentation."

Becklin said SOFIA science will also be able to shed light on key questions about formation of the universe and hydrogen atoms.

"There are some phenomena that we'll see for the first time because of the great resolution. One of those molecules that we'll see in greater detail than anyone has before is the deuderated molecular hydrogen," which is made up of one normal hydrogen atom and one deuterated hydrogen atom.

A hydrogen atom, he explained, has one proton in its nucleus. Deuterium has a proton and a neutron in its nucleus and is called heavy hydrogen. "Now we have heavy molecular hydrogen, a deuterium atom and a hydrogen atom together. With our spectrometers, we can do the best studies that have been done so far on deuderated molecular hydrogen."

It is this hydrogen investigation that could potentially lead to answers about the universe's origins, he said.

"That deuterium we'll be studying will have formed in the Big Bang, and understanding how much [of it] is out there and how it's been destroyed are key questions to trying to understand how the universe began."

A discovery's implications might not be understood until later, such as was true of another of Becklin's observations that currently are a hot topic in astronomy – "buckyballs."

Buckyballs – dubbed C_{60} after their makeup was identified as 60 carbon atoms arrayed in a spherical shape – were discovered by British astrophysicist Harold Kroto, who in the 1980s was at work analyzing radio patterns of carbon in space dust. Their moniker acknowledges 20th century innovator R. Buckminster "Bucky" Fuller, designer of the geodesic dome, the shape of which buckyballs resemble.

Kroto was observing an object in the sky, IRC+10216, of which Becklin had made the first measurements as a graduate student. For lab studies identifying C_{60} and carbon, made to support their astronomical observation, Kroto and a team of researchers received the 1996 Nobel Prize in chemistry.

Buckyballs hold promise because of their superconductivity and for the potential they hold for researchers using them as building blocks for nanotechnology. The carbon balls already have been used for constructing nano tubes that could benefit the medical field. Buckyballs have not yet been identified in space; however, it should be possible to locate them near carbon stars that give off exhaust in much the same way cars on Earth do. Becklin hypothesizes that buckyballs exist in space and will be discovered by the SOFIA when it becomes operational.

"We believe they're probably out there, and we're hoping to see them," he said.

SOFIA mission content will be based on the number of hours available for research and on proposals submitted. Researchers will present their case for use of the SOFIA and peer reviews will determine which proposals are accepted. What is clear is that the SOFIA is certain to observe a wide variety of astronomical phenomena.

Becklin hypothesized that the SOFIA will be engaged in investigations of planets in this solar system and of new planets discovered in other solar systems, in collections of stars, the black hole at the center and edge of the Milky Way and material surrounding it.

"It's hard to predict what will be seen, because discoveries are almost always a surprise," he said.

As a key component of NASA's astrophysics program aimed at exploring fundamental questions about the universe, the flying observatory will add to astronomers' understanding of star birth, formation of the solar system, the nature and evolution of comets, the origins of complex molecules in space, how galaxies form and change and the mysterious black holes in the center of galaxies.

Becklin and his colleagues have their work cut out for them. And they can't wait to get started.

Birds ... from page 7

the astronomical phenomena that can be viewed from that region.

There are tradeoffs with each aircraft, Fullerton said.

Due to the configuration of the stack and its precious – and heavy – cargo, the SCA has a lower threshold for crosswinds compared to that of a production Boeing 747.

The issues that made mission managers reach for the antacids during early SCA flights and in the first SOFIA flights also differ.

Mission managers' concerns about the NASA 747 SCA centered on Enterprise safely separating from the host aircraft and then clearing the SCA's tail during the Approach and Landing Test program.

The 747SP is built for longer-range use than the classic Boeing 747. It has less yaw stability, or motion about the aircraft's vertical axis, because its fuselage is shorter. Concerns about the SOFIA 747SP hinge on modifications that have been made and their impact on the aircraft's structural integrity.

Test flights will determine whether the designs for the beefed-up SOFIA aircraft are correct and completed to specifications. One way a pilot tests the limits of an aircraft is to fly cautiously when engaging maneuvers that stress the aircraft's structure. Those stresses also will be measured with strain gages to validate the aircraft's ability to complete its full range of movements throughout the flight envelope.

"We don't want to hear any popping sounds," Fullerton added wryly.

For Fullerton, one thing is sure – when it's time for him to pilot either aircraft, he'll be ready for whatever it takes to get the big bird safely in the air and down again.

ED07 0118-035 NASA Photo by Tom Tschida

SOFIA Program Manager Bob Meyer, far left, welcomes Dryden pilot Bill Brockett, center, and chief SOFIA pilot Gordon Fullerton to Dryden after the SOFIA aircraft arrived at the center from the L-3 Communications Integrated Systems facility in Waco, Texas.

SOFIA ... from page 2

"The mission control system software ties the science instruments, telescope cavity door and aircraft systems together to use the airplane to point the telescope at a particular celestial object and keep it focused on that object," Austin explained.

The principal advantage of an airborne versus land-based observatory is in the infrared study of the skies. At altitudes of about 41,000 feet, the aircraft is flying above more than 99 percent of atmospheric water vapor, which obscures the infrared spectrum when it is viewed through an Earth-based telescope.

In addition, the SOFIA has a distinct advantage over space-based satellites and space telescopes in that it can be deployed quickly in the event of, say, a comet's appearance and can engage in missions around the globe without the costs of repositioning a space-based telescope. Built to be a sensitive telescope in the infrared and submillimeter spectrum, it is slightly larger than the Hubble Space Telescope, which was designed primarily for observations in the visual and ultraviolet portion of the electromagnetic spectrum.

"We can open up some wavelengths that are impossible to see from any ground-based observatory," Austin said. "We also can fly low-technology-readiness-level instruments because we can integrate the instruments with the telescope, fly the mission and return to our base of operations the following day or following morning. We can afford to use these state-of-the-art instruments that you can't fly in a space-based mission because of technology risks."

Wavelengths are ranges on the electromagnetic spectrum under which astronomical phenomena can be seen. For example, visible light is what can be seen with the naked eye, while infrared light shows a heat signature that can "peer" through dust and atmospheric water vapor that might obscure what can be seen in the infrared spectrum.

Mobility makes the SOFIA a valuable asset.

"It really is a benefit," Austin continued. "We plan to go into the Southern Hemisphere to see the galactic center and as we have targets of opportunity – events like occultation – we can position the aircraft anywhere in the world to take advantage of some really unique things that ground-based observatories are likely not able to get. We also will use the kinds of high-technology instruments at low-technology-readiness levels that the space guys are not likely to have."

An occultation is an astronomical phenomenon observed when a planet or moon passes across the line of sight to another body. An eclipse of the sun is an occultation; such events are used by astronomers to make observations that can't be made under other conditions. One example of the type of information astronomers can glean through an occultation is that, when Pluto is positioned between the Earth and a star, the presence of Pluto's atmosphere is revealed.

SOFIA interior layout

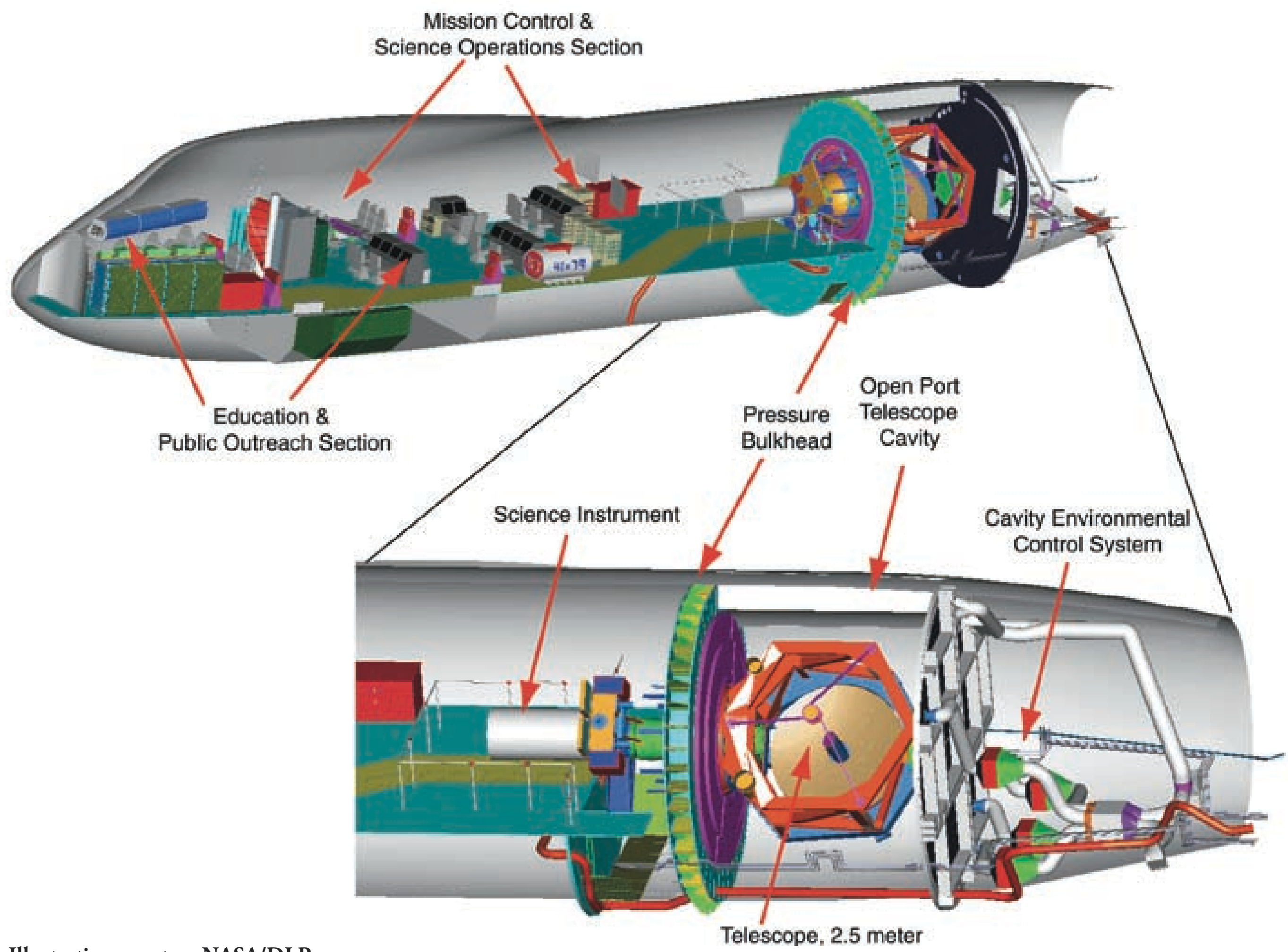


Illustration courtesy NASA/DLR

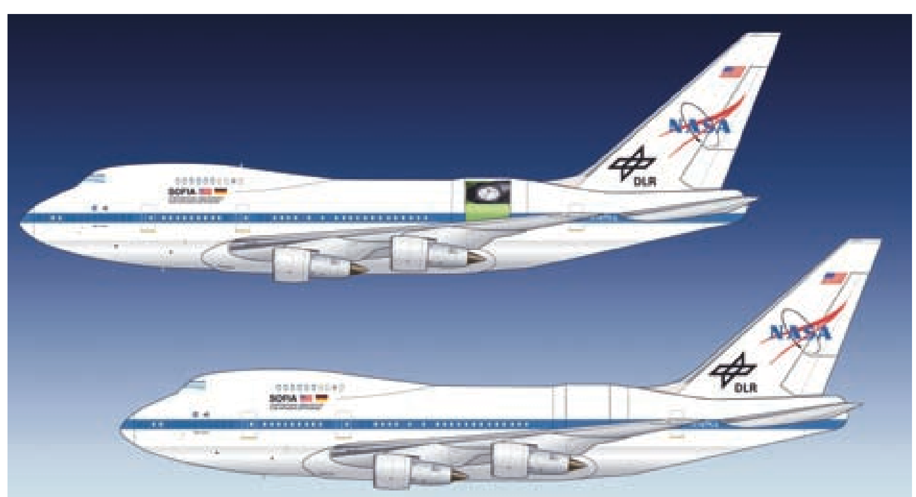


Illustration courtesy Tony Landis/Dryden Flight Research Center

The SOFIA is expected to be an improvement over the storied and now-retired Kuiper Astronomy Observatory aircraft that for 21 years was operated by Ames Research Center, said SOFIA Chief Scientist Eric Becklin.

"One of the things that SOFIA can do that Kuiper couldn't do is – because of its large aperture, it actually has a clearer view of the universe. We'll have a sharper view. In fact, it will be the sharpest view we'll have at some of the wavelengths we're looking at," he said.

Researchers can't be certain what they'll find with the new airborne observatory but judging from past experiences, Becklin said, the possibilities are, well, galactic.

"The most exciting science is really trying to understand the chemistry and, potentially, the biology that's going on in space, and really getting to the heart of the question, did life form here on Earth, or did it form out in space?" he said.

The SOFIA alone won't offer answers to how life began on Earth, but mission planners expect that the science conducted on the aircraft could contribute to new ways of looking at the universe.

There are advantages to using infrared telescopes like the one featured on the SOFIA to study the universe versus using other wavelengths.

"An advantage of infrared [versus other wavelengths] is that it 'peers' through the dust that's out in space," Becklin said. "There's a lot of dust in space; it's between stars. The view that we get of the universe in the optical or ultraviolet (wavelength) is biased by dust. SOFIA will probe right through that dust.

"In the visible and ultraviolet, you're mainly looking at stars. When you look in infrared you see stars, but also see (more clearly) the dust and gas those stars formed from or are throwing off as they die. You really get a different view of the universe when you look in the infrared."

The SOFIA is expected to be a key component of the NASA astrophysics program, aimed at exploring fundamental questions about the universe. The SOFIA will help astronomers learn more about the birth of stars, the formation of solar systems, the nature and evolution of comets, the origins of complex molecules in space, how galaxies form and change and the mysterious black holes at the center of some galaxies – including our own.

Modifications to the Boeing 747SP airframe to accommodate the telescope, other mission-specific equipment and the large external door were made by L-3 Communications Integrated Systems of Waco, Texas.

The science portion of the SOFIA program will be planned by Ames Research Center and managed by Universities Space Research Association, or USRA, of Columbia, Md., and the Deutsches SOFIA Institut, or DSI, of the Universität Stuttgart, Germany.

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