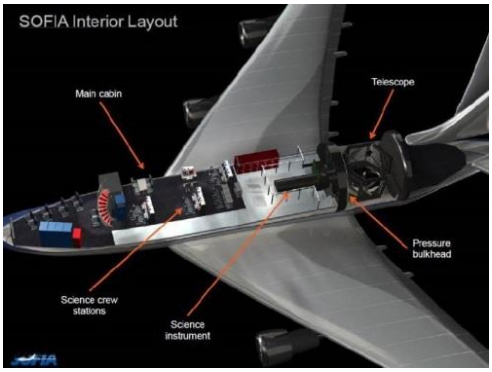
SOFIA – It's Alive

In late 1996, NASA and DLR (German Aerospace Center) agreed to jointly develop and operate a new observatory called SOFIA (Stratospheric Observatory for Infrared Astronomy). SOFIA was planned as successor of NASA's Kuiper Airborne Observatory (Kuiper), which flew from 1974 to 1995.

SOFIA is an airborne-observatory designed to study the universe in the infrared region of the electromagnetic spectrum. SOFIA facilitates research of diverse cosmic environments and collects data to advance understanding of the structure and evolution of the universe.



Built within the frame of a Boeing 747SP, SOFIA contains an internally mounted 2.7-meter (approximately 9-foot) telescope that operators expose to the night sky through a uniquely designed cavity door located at the rear of the plane. NASA designed SOFIA to observe both infrared and visible wavelengths from 0.3 to 1.600 microns.

The observatory is particularly well suited for investigating the formation of massive stars and the environment that leads to the formation of planets.

After integration of the telescope and the completion of the structural modifications flight testing of the aircraft started in April of 2007.

First rumors about the suspension of the project circulated in early 2006, however the continuation was officially confirmed by NASA in July 2006.
The first test flight after the completion of its conversion took off as planned from Waco, Texas on 26 April 2007.
On 21 May 2007 Erik Lindbergh, grandson of Charles Lindbergh, christened the aircraft as *Clipper Lindbergh*.
In January 2008 the operations base of the aircraft was moved to Dryden Flight Research Center Dryden Aircraft Operations Facility at Palmdale, California.

The first test flight with open telescope door was performed in December 2009, the first use of the telescope in flight, the so-called "first light" acquisition was successfully completed on 26 May 2010.

The first scientific observation flight was conducted successfully in November 30 - 1 December of 2010. SOFIA took off from Palmdale, California and performed observations at altitudes of about 13 km with the infrared camera FORCAST (Faint Object InfraRed CAmera for the SOFIA Telescope). Observation target was the constellation Orion.
The full functionality was scheduled for 2014 and about 160 missions with approximately 1,000 hours of observation are performed annually were planned. [1]

As a big surprise to the German partners **mothballing the aircraft** was announced by NASA on Feb 4, 2014:
"NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) reached full operational capability (FOC) after a problematic 23-year development history and a cost of $1.1 billion – more than 300 percent

over original estimates. The SOFIA Program's $3 billion life-cycle cost estimate, which includes a planned 20-year operational life and annual operating costs of approximately $80 million (equating to an annual operating cost of about $104,000 per planned research flight hour), makes it one of the most expensive programs in NASA's science portfolio. While the Program achieved FOC ahead of schedule (per the latest re-planning) and SOFIA has recently begun to collect science data, maintaining user interest is critical to the Program's viability for the next 20 years. More pressing for the Program is the uncertainty caused by the President's fiscal year (FY) 2015 budget proposal that would place SOFIA in storage for an undefined period unless NASA identifies partners to help subsidize operating costs." [2]

The former CEO of DLR J.D. Woerner, was "appalled and upset" over the decision by NASA. [1]

NASA's OIG report IG-14-022 (July 9, 2014) concluded with the (at that time unpublished) recommendation: [2]

Recommendation 10: In anticipation of the end of the current contract with USRA in 2016, consider whether a fixed-price contract would be more appropriate than the current cost-plus-fixed-fee contract.

Management's Response: Concur. NASA recognizes that the current contract with USRA was written during a very different phase in the life of the Program. NASA will evaluate all potential mechanisms for the follow-on contract to ensure that NASA maintains proper oversight, incentivizes the contractor appropriately, and achieves an optimal balance of risk between the government and the contactor. NASA will define the procurement strategy for the follow-on contract by June 30, 2015.

[USRA = Universities Space Research Association]

After the evaluation of "all potential mechanisms" NASA got the funds for the continuation of the German-American project with an 80/20 partnership in the overall budget for FY 2015 finally approved by the Appropriation Committee. [1]

Scientific Results

In summer 2015 SOFIA was transferred to New Zealand to observe the dwarf planet Pluto passing between a distant star and the Earth producing a shadow on the Earth near New Zealand that allowed SOFIA to study the atmosphere of Pluto on 29 June 2015. Such occurrences are relatively rare and in this case the observations by SOFIA could provide specific insights for the Pluto probe New Horizons, which had a scheduled fly-by at this former planet two weeks later. [1]

At the end of 2015, NASA stated the following goals for the SOFIA program:

- Exploration of Pluto
- Promotion of young scientists
- Search for evidence where the water of the earth has its origin
- Links between supernovae and the genesis of planets
- Observation of an extrasolar Planet

Mission Results in 2015 [3]

Posted **January 15, 2015**
The Galaxy's Central Molecular Zone
SOFIA measurements of ionized carbon and nitrogen gas at the edge of the Central Molecular Zone (CMZ) of the Milky Way were made with the GREAT far-IR heterodyne spectrometer (P.I. Rolf Güsten, MPIfR) as a part of SOFIA's Guest Investigator program. The observations were made over the course of several nights in July 2013 during SOFIA's first Southern Hemisphere deployment.
The CMZ is a 400 pc x 80 pc region around the galactic center containing 10 million solar masses of giant molecular clouds, many regions of active star formation, and frequent supernova explosions. Read more

Posted **July 09, 2015**

SOFIA Observes Extrasolar Planet HD 189733b

The first observations of an extrasolar planet by SOFIA are reported in a paper published online on July 8 in the Journal of Astronomical Telescopes, Instruments, and Systems (JATIS) by Daniel Angerhausen (NASA Goddard Space Flight Center and Rensselaer Polytechnic Institute) and collaborators. Read more

Posted **September 23, 2015**

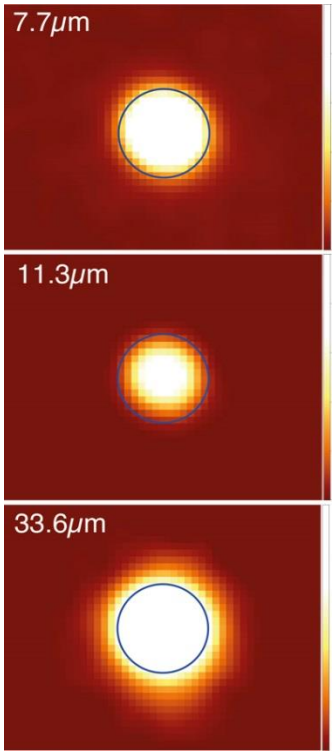
Water Around the Protostar AFGL 2591

An international team led by scientists at Johns Hopkins University and the University of California at Davis used the EXES high-resolution mid-infrared spectrometer onboard SOFIA to determine the amount and location of water molecules around protostar AFGL 2591. AFGL 2591 is object number 2591 in a catalog of strong infrared sources discovered by a series of small infrared telescopes launched in rockets during the 1960s by the Air Force Geophysical Laboratory. Read more

Mission Results in 2016 [3]

Posted **April 29, 2016**

SOFIA Witnesses the Emergence of a Carbon Star



The planetary nebula BD+30 3639 was imaged by SOFIA using FORCAST (Faint Object InfraRed Camera for the SOFIA Telescope; P.I. T. Herter, Cornell University) at wavelengths of 6.4, 7.7, 11.1, 11.3, and 33.6 microns. BD+30 3639 (also known as PN G064.7+05.0) is located at a distance of 1.2 kiloparsecs. (Guzman-Ramirez et al. 2015, Monthly Notices of the Royal Astronomical Society, 451, 1.),

Oxygen (O) is about a factor of two more cosmically abundant than carbon (C), so all stars form from material that is O-rich. The cores of some stars become C-rich through the process of nucleosynthesis as they evolve. Many Asymptotic Giant Branch (AGB) stars are observed to have more carbon than oxygen in their photospheres and envelopes.

This observation is consistent with the dredge-up of material from deep within the star. Such so-called carbon stars are understood to be the primary source of carbon in the Universe. A few other AGB stars, including BD+30 3639, are referred to as "dual-chemistry" systems because their spectra show evidence of both O-rich and C-rich material. Read more

Posted **April 01, 2016**

SOFIA/GREAT Detection of Atomic Oxygen in the Martian Atmosphere

Atomic oxygen is a key component in regulation of energy and mass exchanges within the Martian atmosphere. Neutral atomic oxygen (O I) was detected in the Martian atmosphere at a frequency of 4.7 THz (63 μm) on 14 May 2014 using the high-frequency channel of the far-infrared heterodyne spectrometer GREAT (German Receiver for Astronomy at Terahertz Frequencies; P.I. Rolf Güsten, Max Planck Institut für Radioastronomie) onboard SOFIA. The [O I] line was found in absorption against the Mars continuum with a high signal-to-noise ratio (see figures). Read more

SOFIA's fourth scientific mission started in March 2016 and will be continued throughout the year 2016. In summer 2016 a trip to the southern hemisphere is scheduled again, altogether 106 flights are planned until January 2017.

In the future the infrared telescope SOFIA is intended to explore all astronomical objects such as planets, moons, asteroids and comets in our solar system, but also the exploration of emerging stars and planets, the exoplanets, the space between the stars and even near active galaxies are on the agenda of this mission.

On June 3 2016 NASA and DLR **extended** their SOFIA cooperation agreement to continue observations until the **end of 2020**. [4]

It looks like the long development time and the hurdles to be taken during the past 20 years were very worth the effort. The project managers, technicians, operators and scientists have to be complimented for their tenacity and endurance and now they still have a very intensive scientific exploration program in front of them.

References:

[1] Wikipedia SOFIA, translated from German:
https://de.wikipedia.org/wiki/Stratosph%C3%A4ren-Observatorium_f%C3%BCr_Infrarot-Astronomie
https://en.wikipedia.org/wiki/Stratospheric_Observatory_for_Infrared_Astronomy

[2] NASA Report No. IG-14-022: SOFIA: NASA's Stratospheric Observatory for Infrared Astronomy Office of Inspector General July 9, 2014 Audit Report
https://oig.nasa.gov/audits/reports/FY14/IG-14-022.pdf

[3] SOFIA Science Data Center https://www.sofia.usra.edu/

[4] NASA and German Aerospace Center Extend SOFIA Cooperative Agreement (June 3 2016)
http://www.nasa.gov/centers/armstrong/photo_feature/SOFIA_agreement_extended.html