SOFIA Response to 5-Year Flagship Mission Review

Presented by:

SOFIA Project Scientist

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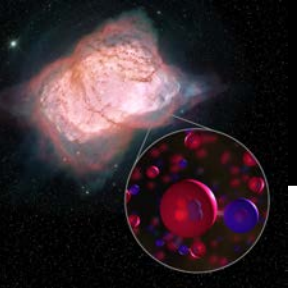
11 December 2020



SOFIA found helium hydride, the first type of molecule to form in the early universe

SOFIA Response to 5-Year Flagship Mission Review

This presentation summarizes the SOFIA Project's response to the Five-Year Flagship Mission Review (FMR) report that recommended a number of concrete suggestions to improve the scientific productivity and impact of SOFIA.

https://www.sofia.usra.edu/science/sofia-overview/steering-documents

SOFIA Discovers Water on Sunlit Surface of Moon

This illustration highlights the Moon's Clavius Crater with an illustration depicting water trapped in the lunar soil there, along with an image of NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) that found sunlit lunar water.

Credits: NASA/Daniel Rutter

https://www.nasa.gov/press-release/nasa-s-sofia-discovers-water-on-sunlit-surface-of-moon/

Dr. Casey Honniball, NASA Postdoc
Goddard Space Flight Center

After 24 hours…

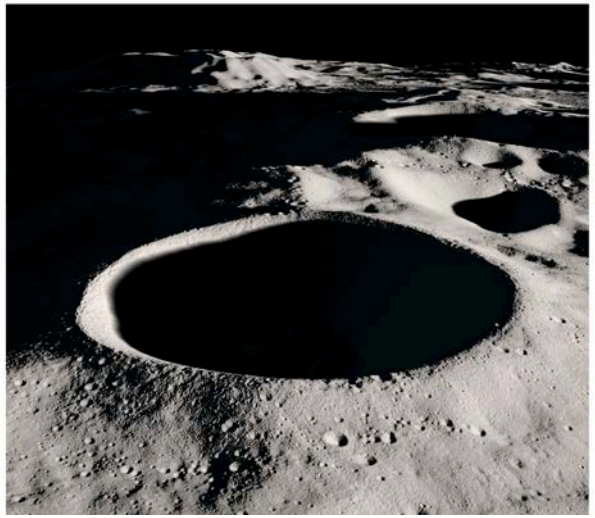
- 3.7K media mentions reaching 76.7M people
- News release: 410k+ views
- 255k YouTube views of the 60-second shareable video
- Peak viewership of 18K people following the telecom on nasa.gov/live
- Daily morning email summaries including the news in USA Today and the New York Times
- 1.6M views on @JimBridenstine Twitter account

Nature Astronomy (2020)

The New York Times

There's Water and Ice on the Moon, and in More Places Than NASA Thought

Future astronauts seeking water on the moon may not need to go into the most treacherous craters in its polar regions to find it.



USA TODAY

NATION

Water discovered on sunlit part of the moon for the first time, NASA says

Doyle Rice USA TODAY

Published 11:02 a.m. ET Oct. 26, 2020 | Updated 4:00 p.m. ET Oct. 26, 2020

NASA's moon water discovery: Find on sunlit part has big imp

The moon discovery indicates that water may be distributed across the lunar surface and places, NASA said. *USA TODAY Handout*

TODAY

NEWS

Neil deGrasse Tyson breaks down discovery of water on the moon

NATIONAL GEOGRAPHIC

A pair of new studies are helping scientists figure out where and how much water could linger o our planetary companion.

NASA/GSFC/ARIZONA STATE UNIVERSITY

SCIENCE

Water on moon's surface may be more abundant than once thought

Two new studies promise to help untangle the moon's mysterious water cy —and could hint at resources for future lunar astronauts.

TIME

SCIENCE • SPACE

NASA Found More Water On the Moon—But Don't Plan On Having a Sip Any Time Soon

SCIENTIFIC AMERICAN 175

Water Found in Sunlight and Shadow on the Moon

Observations by NASA's SOFIA telescope and Lunar Reconnaissance Orbiter reveal signs of water in sun-baked lunar soil, as well as in small, dark craters

By Leonard David on October 26, 2020

Water on the moon

The Washington Post

Science

Pair of studies confirm there is water on the moon

New research confirms what scientists had theorized for years — the moon is wet.

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BEHAVIOR & SOCIETY
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Science

The Moon's soil, especially in polar regions, could hold substantial amounts of water. © ESA/NASA

The Moon may hold much more water than we think

NBC

Moon has more water than previously thought, scientists say

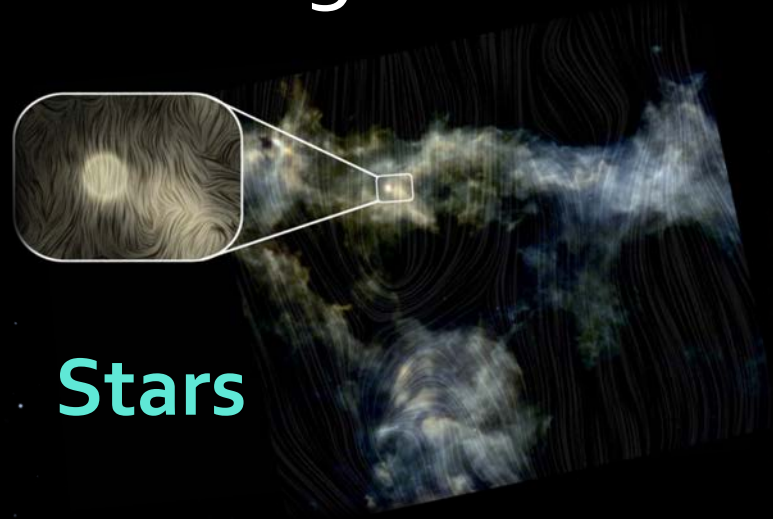
The new finding suggests that water may be present across more of the lunar surface, beyond just areas that are cold and in shadow.

FOX NEWS

NASA confirms water has been spotted on the sunlit surface of the moon

The water was spotted on the southern hemisphere on the moon, near the Clavius crater

SOFIA Impact: Magnetic Field Mapping with HAWC+



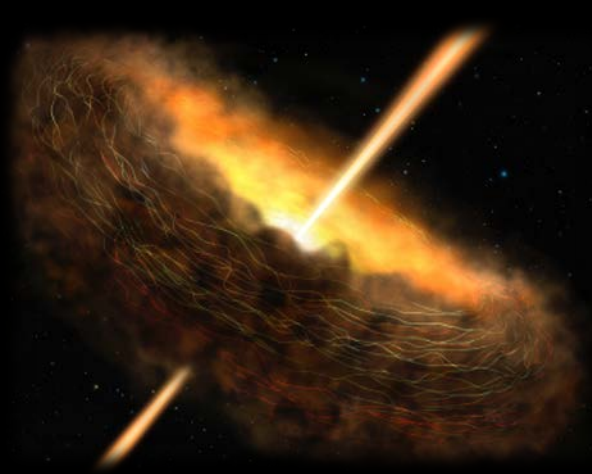
Stars

Sub-pc/pc scales

Galaxies

Kpc scales

Black Holes



Vicinity of supermassive black holes

Mapping Magnetic Fields

SOFIA

SOFIA Impact: Mapping Magnetic Fields

Volume 4 Issue 12, December 2020

A magnetic collapse

How does the interstellar medium collapse into stars in the presence of strong magnetic fields? New SOFIA far-infrared polarimetric observations reveal that gravity drags weakened magnetic fields, allowing the streaming of the magnetized gas along filaments that ultimately feed the star-forming region.

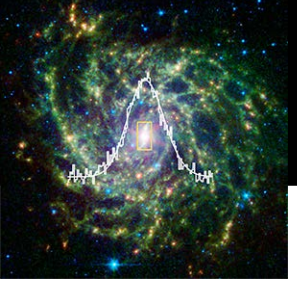
See Pillai et al.

Image: NASA/SOFIA/T. Pillai/J. Kauffmann; NASA/JPL-Caltech/L. Allen Cover Design: Bethany Vukomanovic.

SOFIA in the Past Year: Responding to Reviews, Audits & Implementing Changes

During the past year, the SOFIA Project has responded to multiple reviews and audits:

- **APAC** (Astrophysics Advisory Panel):
  - SOFIA Project Scientist presented the Project's response to the FMR (Flagship Mission Review) and SOMER (SOFIA Operations & Maintenance Efficiency Review) recommendations at a public meeting (**6 Mar 2020**) and in writing one week prior to the public meeting (28 Feb 2020).
  - Additional follow-up requests for information from APAC were addressed in writing by SOFIA Project Scientist in April 2020. SOFIA presented again to APAC in **June 2020**.
- **Project's SOMER Response**, describing analysis & implementation of SOMER recommendations, submitted to NASA HQ/Astrophysics (31 Jan 2020).
- **Stratospheric Hours and Water Vapor Study**: to measure and track observing conditions on SOFIA, the Project conducted detailed analysis on measuring stratospheric hours and water vapor from NASA GEOS weather database to determine the right metric for high-quality observing time. Presented to NASA HQ/Astrophysics (26 June 2020).
- **SOFIA Project Response to Astro 2020 Decadal Survey** Questionnaire submitted to Director for Astrophysics (24 Jan 2020); a second follow-up response to RFIs about SOFIA's Guest Observer program also was submitted (12 Feb 2020); and the project responded again to RFIs on 20 Mar 2020.
- **NASA Office of Inspector General (OIG) Audits**: Project responded to multiple sets of RFIs generated by the OIG.
- **Project's FMR Response**, describing the analysis and implementation of the FMR recommendations, was included as part of the response to Decadal Survey Requests for Information (RFIs) and submitted to the Director for Astrophysics (24 Jan 2020). The formal (stand-alone) FMR response was submitted to NASA HQ/Astrophysics (30 Sep 2020).

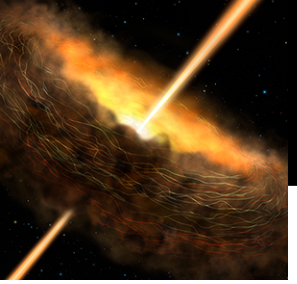


SOFIA data assists in understanding star formation in the nucleus of Galaxy IC 342

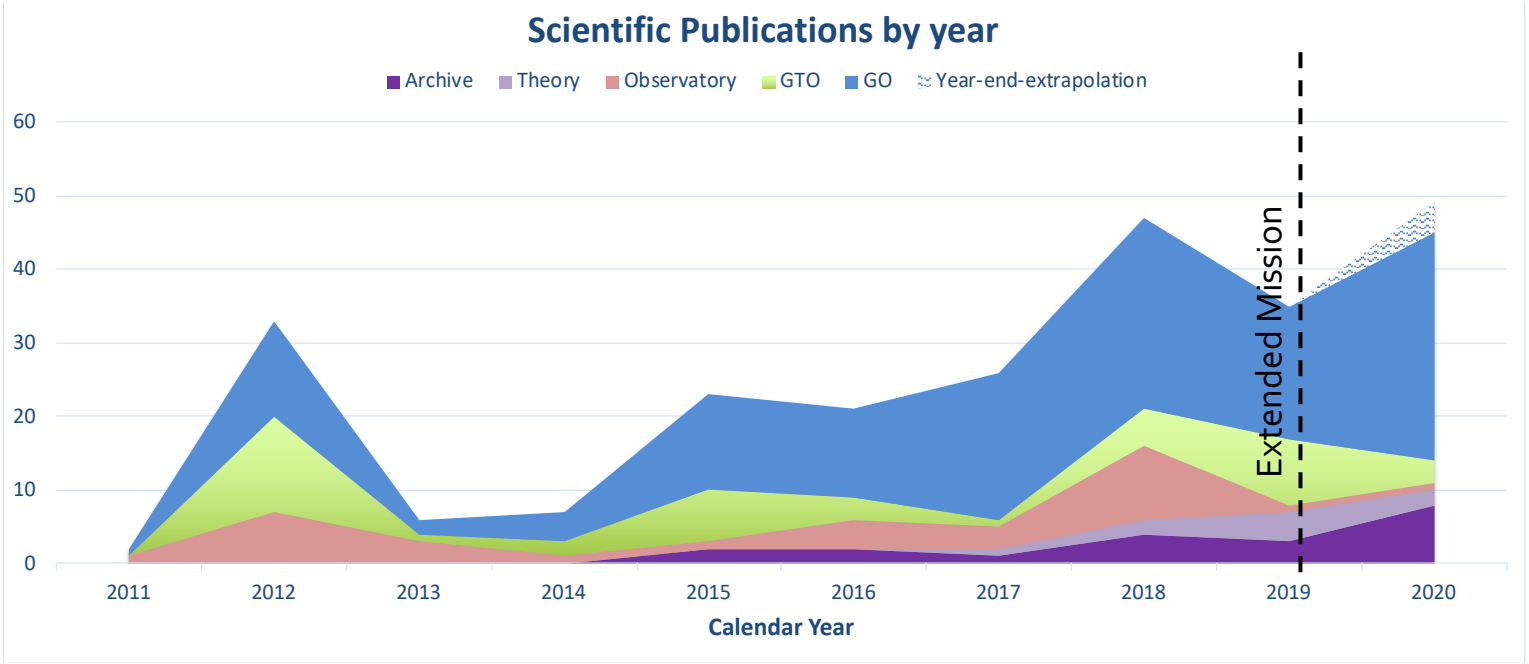
Response to the Flagship Mission Review

- The Stratospheric Observatory for Infrared Astronomy (SOFIA) is currently the **only astronomical observatory in the world to provide access to the far-infrared and major swaths of the mid-infrared wavelength regions**.
- With the advantage of large-scale mapping, high-resolution spectroscopy, and polarization measurements at wavelengths where the thermal signal is strongest**, SOFIA will significantly extend the legacies of Herschel and Spitzer** by making fundamental measurements related to star and planet formation, formation of pre-biotic molecules in the interstellar medium, the role of magnetic fields in the formation of galaxies and supermassive black holes in the local universe, and studying the water cycle and minerology of the Moon to support the Agency's Artemis mission. SOFIA science objectives address NASA's strategic goals described in Table 1.1.
- **SOFIA, a highly complex and versatile airborne astronomical platform, reached mature operations** in its prime mission and transitioned from development and data acquisition to scientific discovery.
- **In the extended phase, starting fall 2019, focus shifted to substantially increasing its scientific output and impact** by raising the fraction of time spent on large coordinated community-driven observing programs; building a strong, diverse, multi-disciplinary science community; providing more observing opportunities in the Southern Hemisphere; increasing observing time during the Northern winter when conditions are optimal; and restructuring the Project to sustain operations within a lower annual budget.
- **The SOFIA Science and Mission Operations (SMO) organization** contributed to this response by conducting a strategic study focused on three themes: impact, productivity, and efficiency, each resulting in several initiatives.

Science Metrics: Publications by Calendar Year



SOFIA reveals that magnetic fields may be feeding active black holes.



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	sum
Archive	0	0	0	0	2	2	1	4	3	8		20
Theory	0	0	0	0	0	0	1	2	4	2		9
GO	1	13	2	4	13	12	20	26	18	31		140
GTO	0	13	1	2	7	3	1	5	9	3		44
Observatory	1	7	3	1	1	4	3	10	1	1		30
Year-end-extrapolation										4	0.0	
sum	2	33	6	7	23	21	26	47	35	49		234

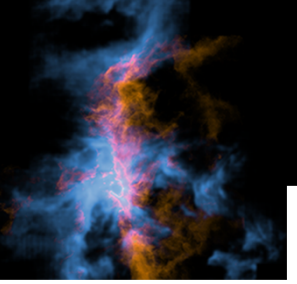
The number of peer-reviewed papers based on SOFIA data are presented by calendar year

- 'Archive' and 'Theory' categories contribute to SOFIA's archival publications
- 'GO and GTO' categories contribute towards science publications
- 'Observatory' publications are related to upgrades and new science instrument capabilities

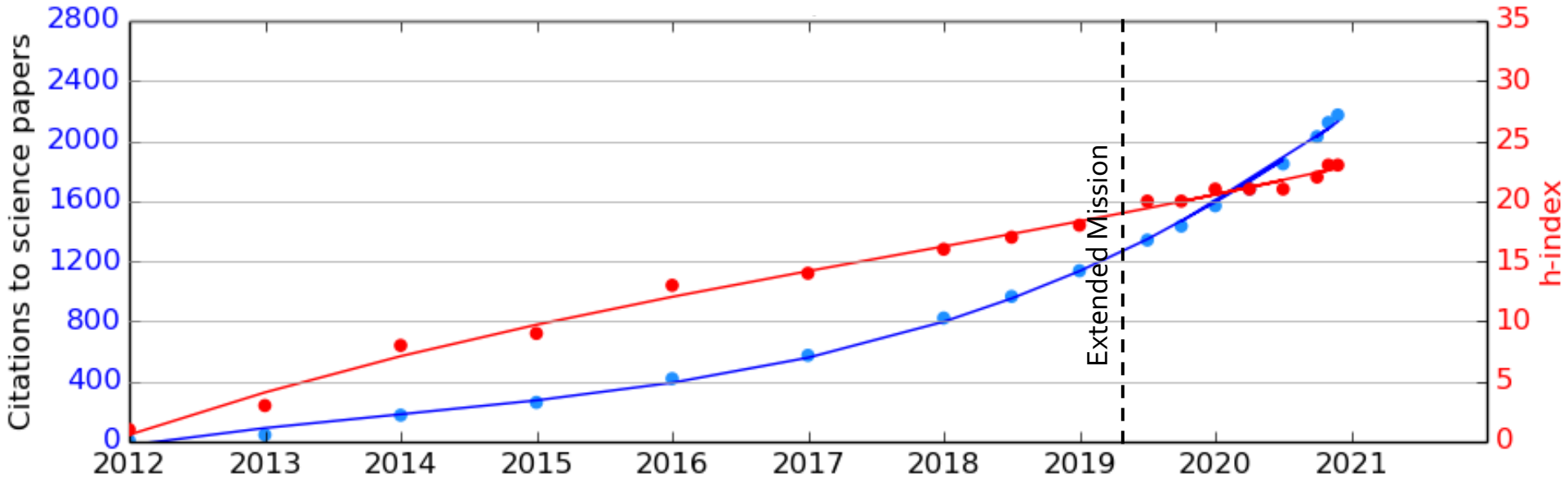
Guest Observer (GO) = awarded observing time through a competed, peer-reviewed proposal process

Guaranteed Time Observation (GTO) = allocated to instrument development teams as reward for developing science instruments

Science Metrics: Impact



SOFIA measures the mechanical energy from stellar winds generated by infant stars



	1/1/12	1/1/13	1/1/14	1/1/15	1/1/16	1/1/17	1/1/18	1/1/19	1/1/20	3/30/20	6/30/20	11/25/20
Citations	8	45	176	261	419	574	822	1137	1569	1669	1812	2173
h-index	1	3	8	9	13	14	16	18	21	21	21	23

★ Scientific impact metrics are presented for the SOFIA Project

- Hirsch (H)-index is a metric for evaluating the cumulative impact of the Observatory's output and performance
- The value of the H-index measures quantity with quality by comparing publications to citations

SOFIA Key Metrics and Goals

Weighing a galactic wind provides clues to the evolution of galaxies. The magnetic field detected by SOFIA, shown as streamlines, appears to follow the bipolar outflows (red) generated by the intense nuclear starburst.

Table 1.4 presents key science metrics recommended by the FMR that have been implemented and are being tracked by the Project.

Table 1.4 – SOFIA Key Metrics and Goals

Science Metric	Goal
Publications per year:	> 75 (100)*
Scientific Impact Citation H-Index[2]:	> 30 (44)*
Oversubscription Rate[3]:	≥ 5
Data Processing and Archiving Time:	15 workdays
Completion Rate for High-Priority Programs[4]:	≥ 80%
Fraction of Completed High-Priority Programs Resulting in Publications[5]:	≥ 80%
High-Quality Observing Time: % research hours[6] at precipitable water vapor < 15 μm % on-sky efficiency[7] at precipitable water vapor < 15 μm	 ≥ 90% ≥ 90%

** stretch goals are in parentheses*

[2] The H-index, a cumulative impact metric, measures quantity with quality by comparing publications to citations.
[3] Oversubscription rate = observing time requested/observing time awarded.
[4] High-Priority programs are ~75% of the total awarded programs and are labeled priority 1 (P1) and priority 2 (P2).
[5] Typically, there is a 2-year lag from data collection to publication.
[6] "Research hours" are defined as hours when the telescope door is open and observatory systems are ready to collect data.
[7] "On-sky efficiency" means the time that SOFIA is collecting data where atmospheric water-vapor content is low.

SOFIA Mission Objectives

Table 1.2 – SOFIA Mission Objectives*

	PRIORITIZED MISSION OBJECTIVES FOR THE NEXT 5 YEARS
1	Dedicate at least one-third to one-half of observing hours to Legacy programs
2	Maximize observing time in the Southern Hemisphere
3	Emphasize high-quality data collection; effort includes, but is not limited to: a. Maximizing observing in low water-vapor conditions b. Increasing observing opportunities during optimal observing months c. Conducting a robust proposal selection and technical evaluation process d. Prioritizing the collection of well-characterized, well-calibrated, large, homogeneous data sets
4	Pursue synergies with ground-based observatories and NASA missions via collaborative efforts and joint observing programs
5	Build a bigger and a scientifically diverse user community
6	Maintain the capability to upgrade and develop new instrumentation to support new discoveries or new astrophysics priorities

** SOFIA's prioritized mission objectives have been defined in response to the FMR; and, these objectives will be documented in the new Project Plan, which is under development for the extended mission.*

SOFIA Major Initiatives in 2019-2020

SOFIA reveals evidence that parts of the nebula formed separately to create the swan-like shape seen today

Table 1.3 – SOFIA Major Initiatives in 2019-2020

Science Selection, Implementation, and Delivery

Legacy programs will be a larger fraction of total observing time
- 25% in Cycle-8 starting 2020; the goal is to increase this fraction in subsequent cycles
- Introduction of pilot Legacy programs

Joint observatory proposals to broaden SOFIA's impact and user base
- Cycle-9 call for proposals includes a joint observatory call

Reliable and consistent tracking of observing conditions using satellite data
- Provides reliable and consistent water-vapor values
- Will be used for flight planning and scheduling observations to optimize data quality

Observing proposals to stay alive over two cycles, beginning 2021 in Cycle-9
- Higher program completion rate, fewer instrument swaps, greater schedule flexibility

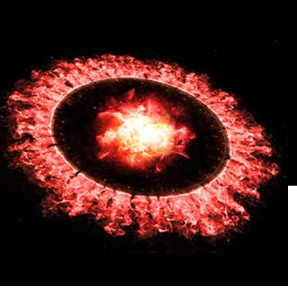
Change in policy for priority-2 programs to be completed once started
- Boost program completion rate and publications

Implemented additional, more thorough technical review of the proposals
- Ensure that selected observing proposals are feasible and publishable

Strategic use of director's discretionary time
- Stronger community involvement, wider mission appeal (e.g., Moon water mapping)

Faster data delivery to the community
- Deliver data in 15 workdays; reduced exclusive-use period to 6-months in Cycle-9

SOFIA Major Initiatives in 2019-2020

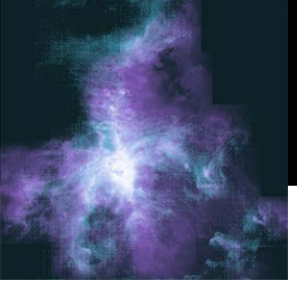


Dust survives obliteration in Supernova 1987A

Table 1.3 – SOFIA Major Initiatives in 2019-2020 (continued)

Observatory Operations
Extended Southern Hemisphere deployment in Cycle-9 (starting in 2021) with a combination of single long deployment plus a mini deployment – Increase observing opportunities in the Southern Hemisphere to 40 nights – Conducted evaluation of alternate Southern Hemisphere deployment sites to allow flexibility to execute mini-deployments when scientifically merited
Automated flight planning – Better agility to respond to delays/rescheduling due to weather or technical issues – Allows more accurate flight plans around restricted airspace
Cross-training staff and identifying on-call back-up mission operations staff to improve observatory efficiency
Reduced aircraft maintenance downtimes to once per year
Shorter (more frequent) flights in spring and fall months to optimize data quality
Implementation of new mission prep tool has significantly reduced pre-flight prep time

SOFIA Major Initiatives in 2019-2020

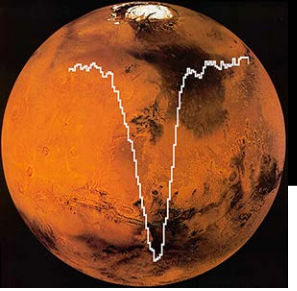


First signs of star birth caused by Orion's wind

Table 1.3 – SOFIA Major Initiatives in 2019-2020 (continued)

PROJECT ORGANIZATION
~10% reduction in workforce in fall 2019 – Maintain staff for sustained 4 flights/week for weekend support, for observatory maintenance, and to conduct Southern Hemisphere deployments
Project reduced to two divisions: Science & Operations – Observatory systems, sustaining and development engineering dramatically downsized – Reduced management overhead; observatory configuration changes limited to mission-critical upgrades required to maintain current operations
SMO reorganization with primary focus on increasing science productivity and impact – More post-docs hired; faster data delivery to the community – Higher focus on community engagement to build impactful and ambitious Legacy programs, increase and broaden SOFIA's impact and user base, promote archival research

FMR Recommendations



SOFIA detects atomic oxygen in Martian atmosphere

Table 3.2 – FMR Recommendations

Top-level Recommendations

1	Devote a larger fraction of total observing time to Legacy programs
2	Aggressively pursue synergies with other missions/observatories
3	Maximize high-quality observing time
4	Increase research hours through flight operations initiatives

Ten Specific Recommendations

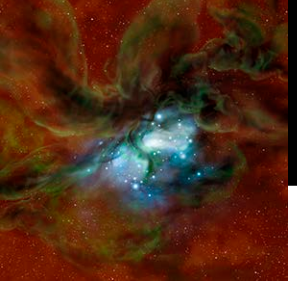
1	Nurture a science-driven culture within the mission
2	Embrace change in operational approaches
3	Emphasize completion of high-priority science programs
4	Emphasize the collection of high-quality data
5	Maximize observing time at stratospheric altitudes
6	Fly more Southern Hemisphere flights
7	Transfer data products into the archive quickly
8	Split aircraft operations from telescope/science operations
9	Invoke HIRMES cost and schedule control
10	Focus on current science operations rather than future science instrument development

SOFIA Legacy Programs

SOFIA mid-infrared Legacy program survey of central regions of the Milky Way reveals features never seen before

- **The Project is fully committed to implementing ambitious "Legacy" programs**
  - Both community- and observatory-led (still community driven), that will have long-lasting legacy value and will enhance SOFIA archival research.
  - Legacy programs will be a larger fraction (more than one-third) of total observing time in accordance with the FMR panel recommendation.
  - For Cycle-8, the 5 legacy/pilot legacy programs contribute ~25% of the total awarded time in Cycle-8.
    - **The use of pilot programs** is newly established to test the efficacy of scientifically promising Legacy programs, by first awarding a small amount of the total requested time. The GO teams can demonstrate the feasibility and potential impact of their programs; and, if successful, the pilot programs are promoted to full Legacy programs in the subsequent years, thereby considerably increasing the fraction of total time devoted to Legacy programs. The pilot Legacy programs allow quick data access and have a positive impact on the publication rate.

Synergies with other NASA Missions/Observatories



SOFIA unravels the mysterious formation of star clusters

Since publication of the FMR report, the Project has collaborated with:

- The Volatiles Investigating Polar Exploration Rover (VIPER) mission
  - Project reached out to the VIPER mission and has implemented a pilot Legacy program to map water on the Moon covering polar regions and other key sites.
  - Follow-up observations will provide more information about how easily water might be accessed by future missions, such as the Artemis lunar exploration program.
- Space Telescope Science Institute (STScI)
  - Using Director's Discretionary Time (DDT), SOFIA SMO and STScI are collaborating on a SOFIA-Hubble demonstration project on Young Stellar Object outflows.
  - SOFIA Cycle-9 observing time (20 hrs.) earmarked to support JWST Early Release Science.
- Green Bank Observatory
  - Joint call for proposals negotiated to use Green Bank Telescope and SOFIA for Cycle-9.
- Atacama Large Millimeter/submillimeter Array (ALMA)
  - Under consideration, earmarking SOFIA observing time for synergistic ALMA observations.

High-Value Observing Time

SOFIA helps answer the question: Is the magnetic field dragging the material toward the super massive cluster of ~1,000 stars in the large Magellanic cloud?

- The FMR report encouraged the Project to substantially increase high-value observing time available to the community. "High-value" was defined as time spent at altitudes > 40,000 feet, considered to be the stratosphere. The panelist report states "…the single greatest impediment to increasing science productivity is the limited amount of high-quality observing time available…" (FMR Report, June 7, 2019, p. 2).
- In response, the Project conducted a study to first evaluate SOFIA's operational success at providing high-value observing time to the community.
- To increase high-value observing time, the Project will be spending **more time in the Southern Hemisphere**, particularly between May and October, when observing conditions from the Northern Hemisphere (Palmdale) are not ideal. This will be achieved by conducting "**mini-deployments**" (~8 flights) in addition to the annual (long) Southern Hemisphere deployment (June-August). The first mini-deployment is solicited in the Cycle-9 call for proposal.
- Project establishing **alternate deployment sites**. The first site survey in Tahiti is complete. It was determined that SOFIA can operate out of there. The next site survey to Argentina is on hold due to COVID-19.

Growing SOFIA Science Community

SOFIA reveals the complex nature of a "simple" star formation tracer

- Even though not specifically called out in the FMR report, the mandate to significantly increase SOFIA's influence in the field of astrophysics and planetary sciences and to implement impactful Legacy programs requires a stronger, larger, multi-disciplinary SOFIA community base.
- The Project will develop strategies to (1) expand and diversify SOFIA's scientific reach (e.g., Moon Legacy), (2) considerably grow HAWC+ user base to maximize the impact of this new capability, (3) increase the usage and visibility of SOFIA archival data and build strategic partnerships or collaborations with other missions and observatories.

SOFIA shows magnetic field alignment over an entire galaxy.

FMR Recommendation #1: Nurture a Science-Driven Culture within the Mission

- Culture change has occurred within the Project at all levels
- Change in leadership with the focus on science
- Change in culture is needed outside of the Project and with our key stakeholders
- Science and community first mentality is needed (less focus on the "aircraft"). Some examples are:
  - Our newsletter focuses primarily on science stories
  - Changing the way we talk about SOFIA at conferences/workshops

SMO's science-driven culture (SMO's presentation by Margaret/Bernhard)

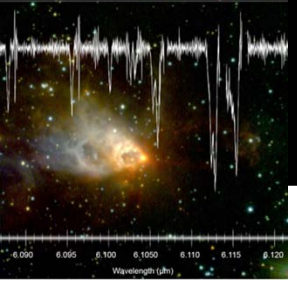
SOFIA observations fuel debate about the origin of the Earth's oceans

FMR Recommendation #2: Embrace Change in Operational Approaches/Simplify Operations

- SMO Efficiencies: Automation and Cross-training
- Evaluating Productivity of Science Instruments and Observing Modes
- Reduction in the Number of Instrument Changes
- Software Upgrades

SMO's presentation by Margaret/Bernhard

FMR Recommendation #3: Emphasize Completion of High-Priority Science Programs



SOFIA pinpoints water vapor in a young star

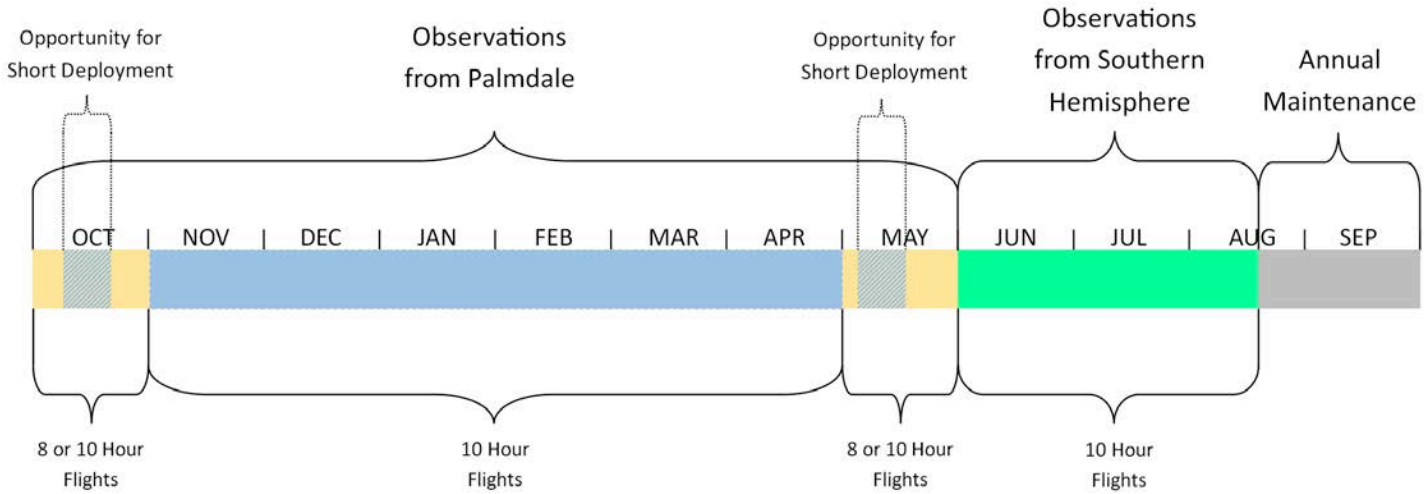
- Raised the completion rate of high-priority science programs by changing the way science flights are scheduled and planned
- The new scheme divides selected proposals in primarily three categories: priority 1 (P1), priority 2 (P2) and priority 3 (P3 or "filler").
  - P1 and P2 combined make up roughly 75% of the selected proposals
- Priority 2 programs, once started, will be completed.

SOFIA detects cosmic fireworks of massive star formation

FMR Recommendation #4: Emphasize the Collection of High-Quality Data

- Data quality on SOFIA depends on various factors:
  1. Maximizing observing time in low water-vapor conditions
  2. Selection of observing programs
  3. Planning and scheduling of observing programs
  4. Execution of observing programs

Figure 6.1 – Ideal Observing Schedule: Maximizing Science Return and Data Quality



SOFIA shows magnetic fields may be keeping Milky Way's black hole quiet

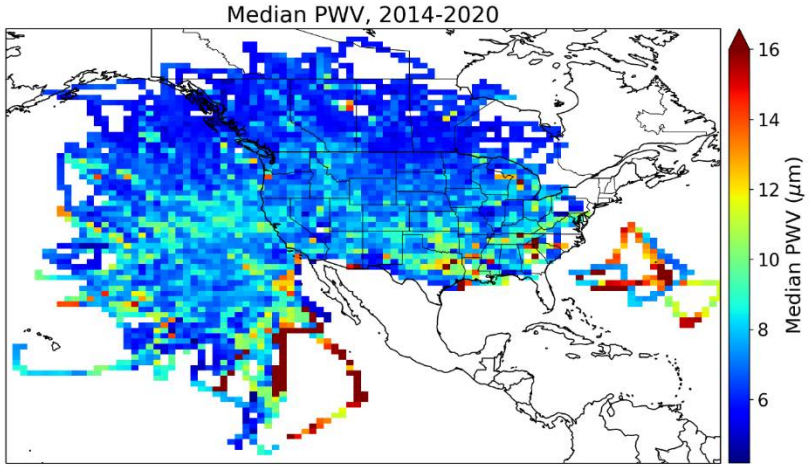
FMR Recommendation #5: Maximize Observing Time at Stratospheric Altitudes

- The FMR and SOMER panels assumed that stratospheric altitudes are typically > 40,000 feet.

- The quality of SOFIA data depends on various factors such as:
  - Observing conditions
  - Selection of science programs
  - Scheduling of science programs
  - Execution of science programs

  Selection of science programs → Operations

  Scheduling of science programs, Execution of science programs → SMO



- The Project led a study to figure out a reliable and consistent method of measuring and tracking high-value observing time, i.e., operationally, is SOFIA providing sufficient high-value observing time?
- We concluded that the NASA GEOS weather database provides reliable measurements of stratospheric height and zenith water vapor.

SOFIA's observations of a comet's first passage through the Solar System

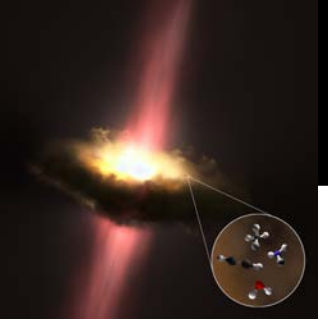
Major Findings & Conclusions

- NASA GEOS weather database is an excellent resource to reliably, consistently and efficiently measure and track high-value observing conditions on SOFIA
- The zenith water vapor is the right metric for measuring and tracking observing conditions on SOFIA
  - Observing conditions are found to be very good (i.e., low water vapor < 15 precipitable microns), and excellent (water vapor < 10 microns), even when SOFIA is technically not in the stratosphere
  - For all North American SOFIA flights since 2014, SOFIA spent 76% of the research hours* in excellent conditions (< 10 microns) and 93% in very good conditions (< 15 microns)
  - For all NZ flights since 2014, SOFIA spent 91% of the time observing in excellent conditions (< 10 microns) and 99% in very good conditions (< 15 microns)

Operationally, SOFIA is providing optimal observing conditions to the science community for conducting high-quality infrared astronomical observations

*Research hours are defined as hours when the telescope door is open and observatory systems are operational and ready to collect data.

Major Findings & Conclusions

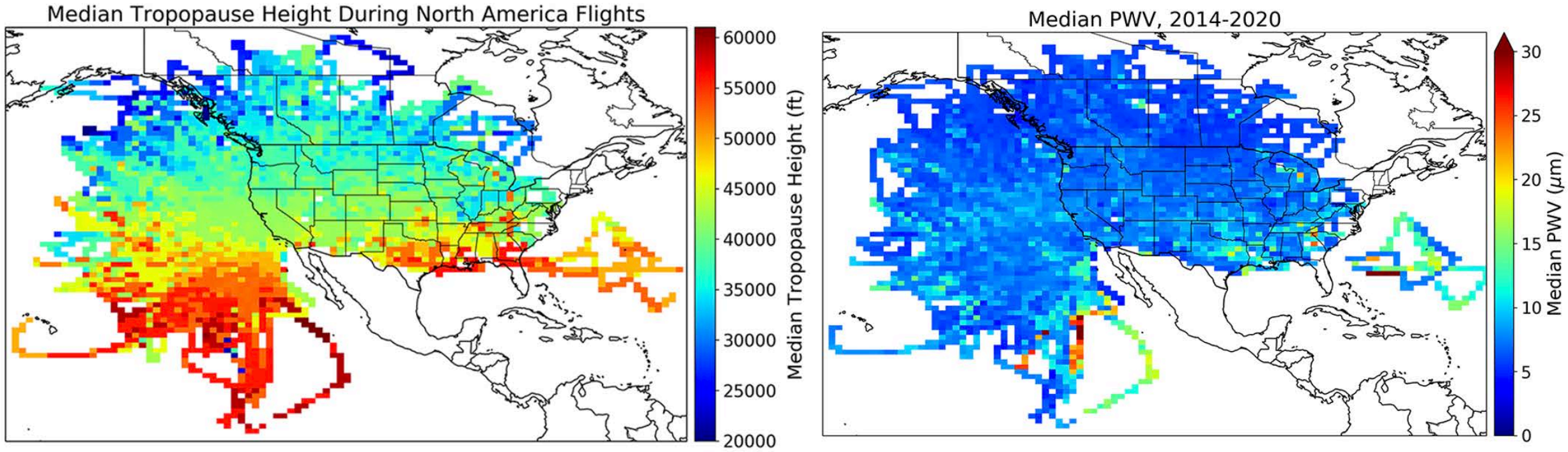


SOFIA provided a new glimpse of the chemistry in the inner region surrounding massive young stars where future planets could begin to form

- Stratospheric altitude (SA) is not the right metric to track high-value observing time
  - SA varies significantly during the flight
  - SA depends strongly on weather and location; SOFIA is not technically in the stratosphere even at altitudes > 40,000 feet due to these factors
  - Stratosphere in NZ can be as low as 34000 feet
  - The adoption of this metric will overly constrain SOFIA operations
- The transitional altitude begins at 38,000 feet for North American operations
  - Chances of excellent observing conditions increase by a factor ~2 between 38K and 39K (using data from all North American SOFIA flights since 2014) and a factor of 3 higher for flights between May-Oct
- Project recommends the following metrics
  - Research hours at Zenith Precipitable Water Vapor (PWV) < 15 microns
  - On-sky efficiency at Zenith Precipitable Water Vapor (PWV) < 15 microns
- 36-hour weather update before the mission from NASA GEOS is very accurate
  - Can be used to fine tune or change flight/observing plan to preserve the quality of observations

Major Findings & Conclusions

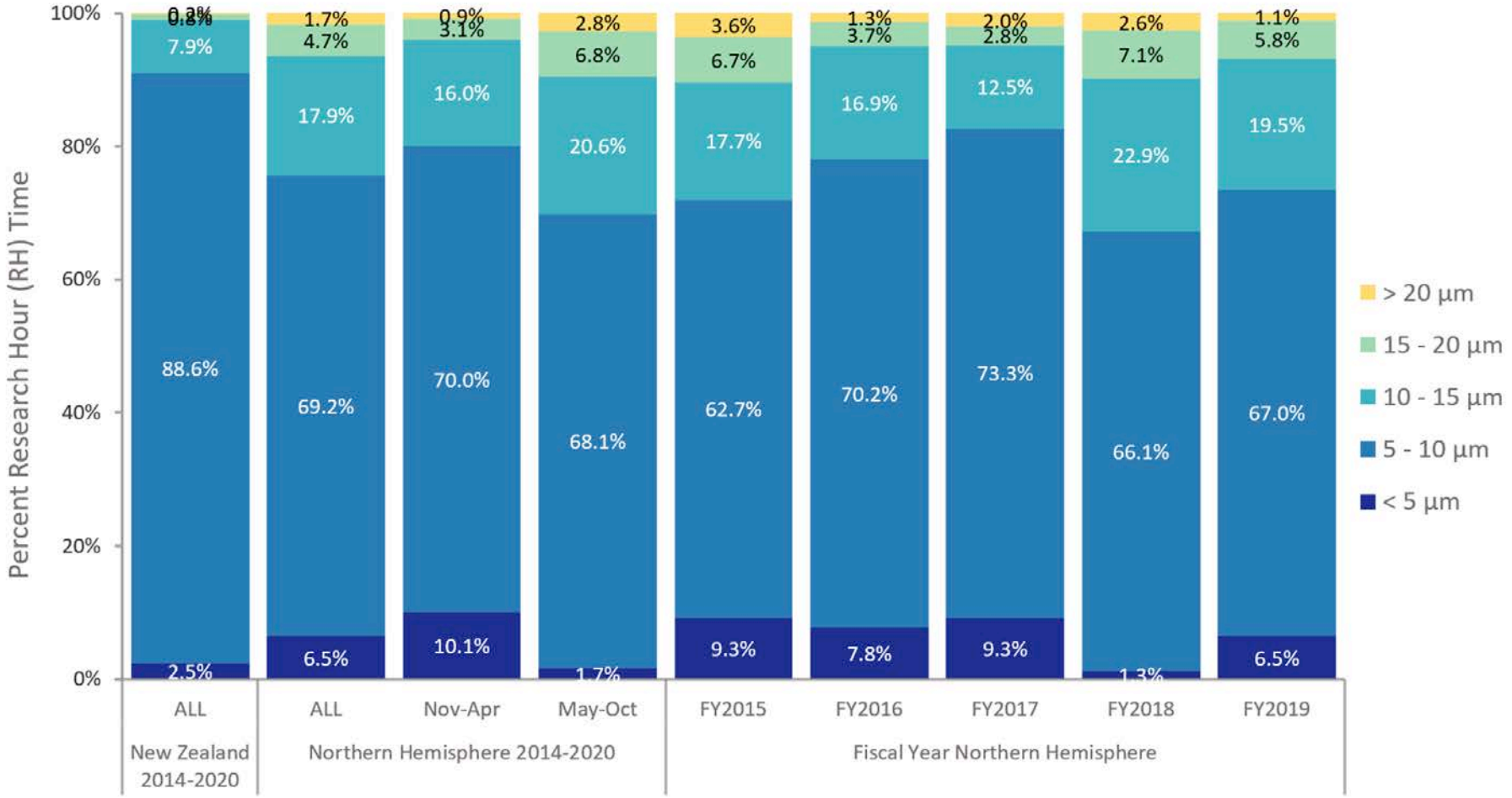
Figure 6.2 - Stratospheric Heights vs. Zenith Water Vapor: All North American SOFIA Flights



* *PWV = Precipitable Water Vapor*
* *Tropopause = boundary between troposphere and stratosphere*
* *Maps are based on SOFIA's actual flight paths for the research hours portion of the flights; maps do not include data between June and August when SOFIA is observing in the Southern Hemisphere*

Major Findings & Conclusions

Figure 6.3 – Zenith PWV from Satellites (All Flight Levels)



Observing conditions are categorized as:

- Excellent: < 10 µm
- Very good: 10 - 15 µm
- Acceptable*: 15 - 20 µm

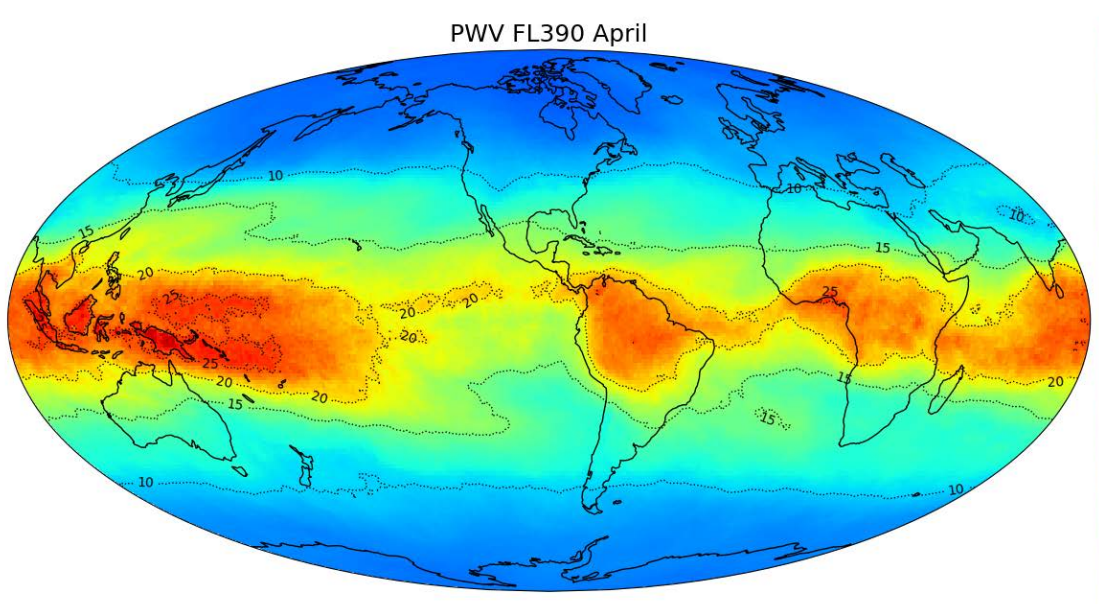
** highly dependent on wavelength, SI, and specific science observation*

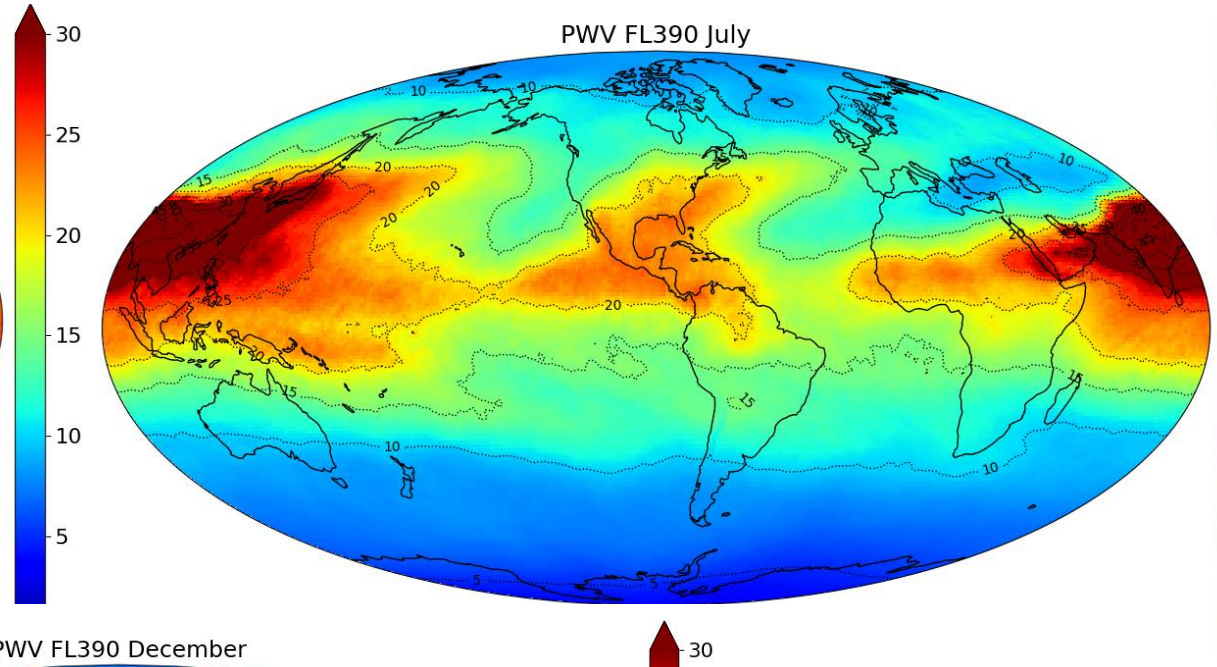
* *May-Oct data are skewed towards lower PWV, because SOFIA typically does not conduct operations between June – August from Palmdale.*

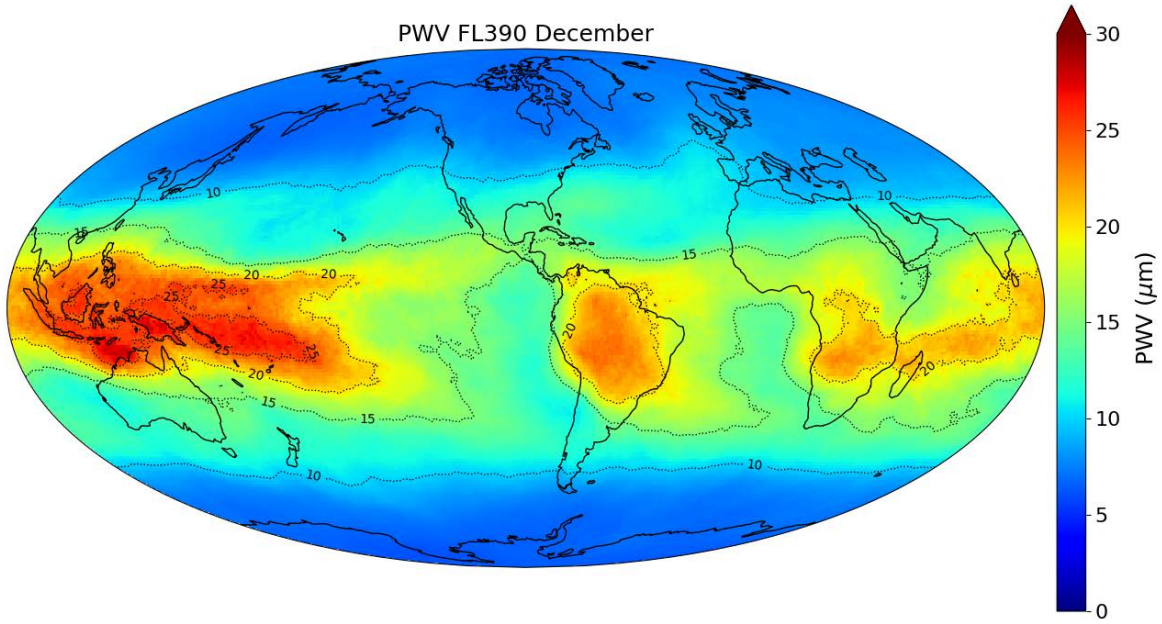
* *During June, July & August, "very good" water-vapor conditions occur less frequently, and shorter flights are recommended.*

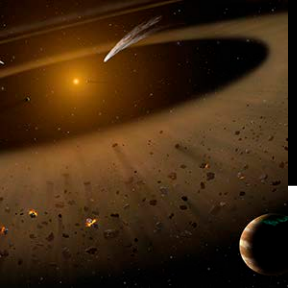
* *Research hours are defined as hours when the telescope door is open and observatory systems are operational and ready to collect data.*

SOFIA Global Precipitable Water Vapor Maps (all months)









SOFIA confirms nearby planetary system is similar to our own

FMR Recommendation #7: Transfer Data Products into the Archive Quickly

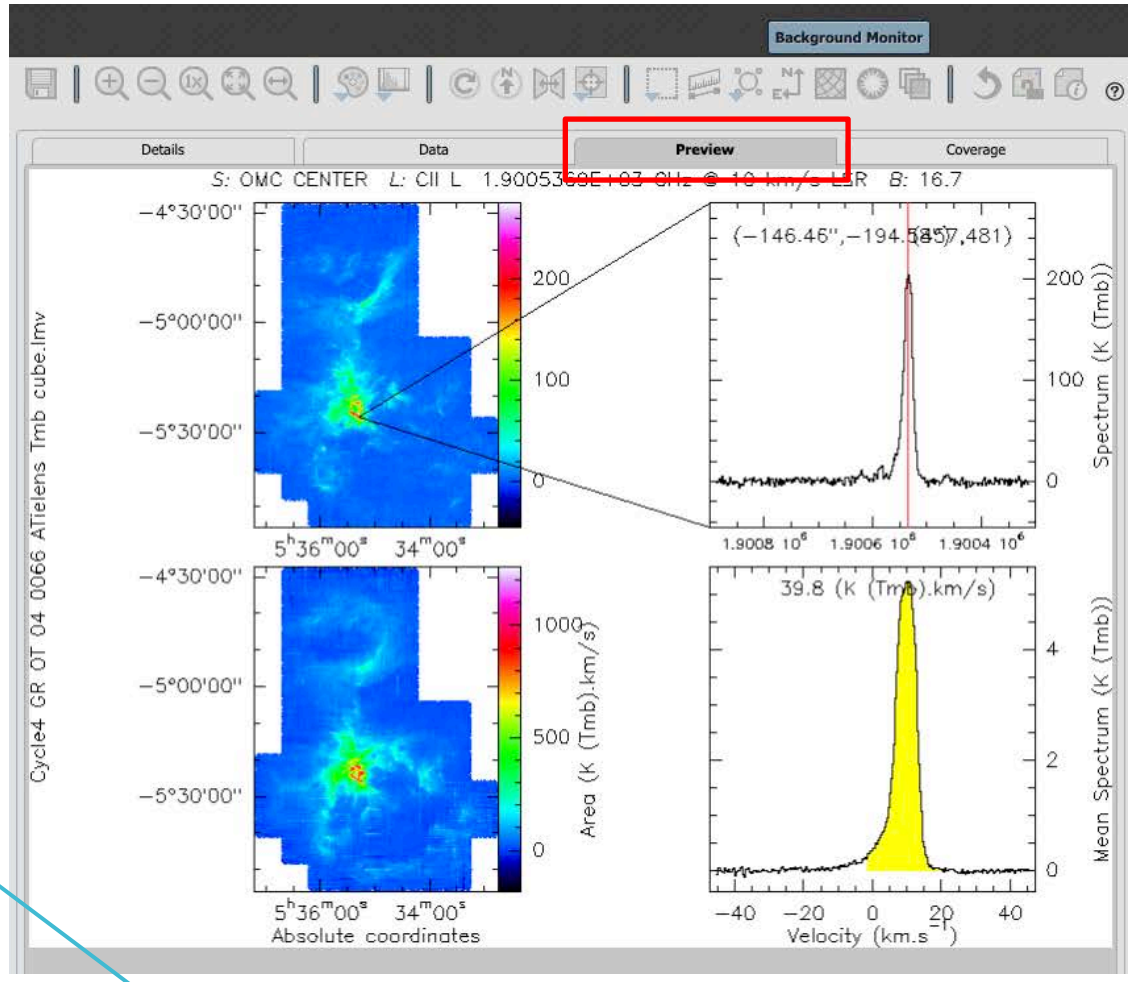
- Goal is to have >70% flux-calibrated level-3 data archived within 15 working days.
- The SOFIA science data archive fully transitioned to the Infrared Science Archive (IRSA) effective March 31, 2020.

  IRSA located at the Infrared Analysis and Processing Center (IPAC) https://irsa.ipac.caltech.edu/applications/sofia
- IRSA makes SOFIA data searchable using a well-known and standardized graphical user interface and places SOFIA data in a context that encourages and aids multi-mission research in infrared astronomy .

SOFIA/IRSA Archive Release 3 (2020 December 9)

Improvements include:

- Data from all instruments, all cycles
- Application program Interface
- Preview images
- Data Discovery tool
- Advanced visualization features
- Publication links



AOR | EXES | FIFI-LS | FLITECAM | FORCAST | FPI+ | GREAT | HAWC+

1 of 3 (1 - 100 of 261)

AOR ID	Target Name	NAIF ID	Instrument	Plan ID	Proposal PI	Abstract Link	Publications Link
char	char	char	char	char	char	char	char
70_0609_74	OMC1-1		HAWC_PLUS	70_0609	Darren Dowell	abstract	publications
70_0609_76	OMC1-2		HAWC_PLUS	70_0609	Darren Dowell	abstract	publications
70_0609_75	OMC1-1		HAWC_PLUS	70_0609	Darren Dowell	abstract	publications
70_0408_4	OrionBar		FIFI-LS	70_0408	Alfred Krabbe	abstract	publications
70_0408_6	OrionBar		FIFI-LS	70_0408	Alfred Krabbe	abstract	publications
70_0408_7	OrionBar		FIFI-LS	70_0408	Alfred Krabbe	abstract	publications
70_0400_3	orion barn p3s-1		FORCAST	70_0400	Terry Herter	abstract	publications
70_0400_2	orion barn p2s-1		FORCAST	70_0400	Terry Herter	abstract	publications
70_0400_1	orion barn p1s-1		FORCAST	70_0400	Terry Herter	abstract	publications
70_0002_48	orion barn p2		FORCAST	70_0002	Luke Keller	abstract	publications
70_0002_47	orion barn p1		FORCAST	70_0002	Luke Keller	abstract	publications
70_0002_46	orion barn p3		FORCAST	70_0002	Luke Keller	abstract	publications
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04_0120_16							
04_0120_17							
04_0066_0010608	OMC_CENTER		GREAT	04_0066	Alexander Tielens	abstract	publications

author	title	publication	doi_link	proposal_ids
Chuss, D	HAWC /SOFIA Multiwavelength Polarimetric Observations of OMC-1	2019ApJ...872..187	DOI	70_0609
Jones, T	SOFIA Far Infrared Imaging Polarimetry of M82 and NGC 253: Exploring the Super?Galactic Wind	2019ApJ...870L...9J	DOI	70_0609
Lopez-Rodriguez, E	SOFIA/HAWC traces the magnetic fields in NGC 1068	2020ApJ...888...66	DOI	70_0609

SOFIA Stratospheric Observatory for Infrared Astronomy

SOFIA finds cool dust around energetic active black holes

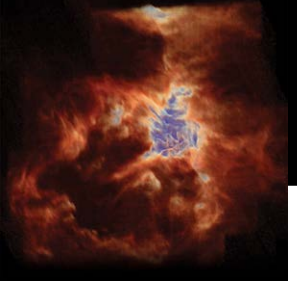
FMR Recommendation #8: Split Aircraft Operations from Telescope and Science Operations

- The SOMER-recommended approach of splitting the aircraft from the observatory systems would not improve either the observatory's operational efficiency or scientific productivity nor would it realize cost savings
- In alignment with the core intent of this FMR/SOMER recommendation, the Project has streamlined aircraft operations by:
  - Significantly reduced observatory systems budget to bolster science operations
  - Restructured the overall organization to minimize complexity and to achieve sustainable operations model within a lower annual budget

SOFIA data reveals magnetic fields in the Orion nebula

FMR Recommendation #9: Invoke HIRMES Cost and Schedule Control

- The HIRMES development was terminated by NASA SMD on April 1, 2020, citing significant technical, cost and schedule risks.
- NASA SMD also was concerned that continuing to fund HIRMES would have impacted important SOFIA activities and would have limited the Project's ability to increase SOFIA's scientific return.
- SOFIA Project was directed to develop a roadmap for future instrumentation. This is done.

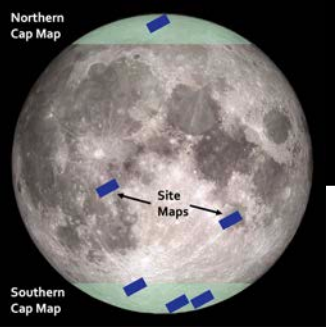


SOFIA 3D Data Cube of Orion's Dragon

FMR Recommendation #10: Focus on Current Science Operations rather than Future Instrument Development

- At the time of the release of the FMR report, HIRMES was still under development.
- This recommendation assumed that the Project would introduce new science capabilities from HIRMES by 2021.
- The SOFIA Project embraces this recommendation and in the near-term will primarily focus on significantly enhancing its scientific productivity and impact by prioritizing acquisition of high-quality science data with the current suite of instruments.
- The instrument roadmap will inform future instrumentation and upgrades.

SOFIA Bold Initiatives – 2020-2021



Mapping water on the Moon, SOFIA pilot Legacy program; image shows locations of 6.1μm site maps on the lunar surface

Bold Initiatives	
1	**Pursue large coordinated Legacy programs** Coordinated with multiple observatories; using fewer, and the most productive, instruments. Approach significantly increases scientific impact while simplifying operations and data processing.
2	**Grow the SOFIA science community** By building multi-disciplinary teams involved in large coordinated, multi-observatory programs.
3	**Increase the total number of flights in Southern Hemisphere to 50 annually**. This will be achieved with a combination of one 30-flight annual Southern Hemisphere deployment and two 10-flight mini-deployments. This change will meet the community's demand by increasing the current Southern Hemisphere observing opportunities by ~50%.
4	**Convert EXES and GREAT** From principal-investigator (PI)-operated to facility-operated science instruments (SI) to meet the community's demand and to substantially increase the impact of these SIs. GREAT Update: For near-term only, pursue augmenting SMO support to increase GREAT flights for the community
5	**Build the operational capacity to plan for five 10-hour flights per week**.

Discoveries are made possible by a multi-disciplinary and talented SOFIA team

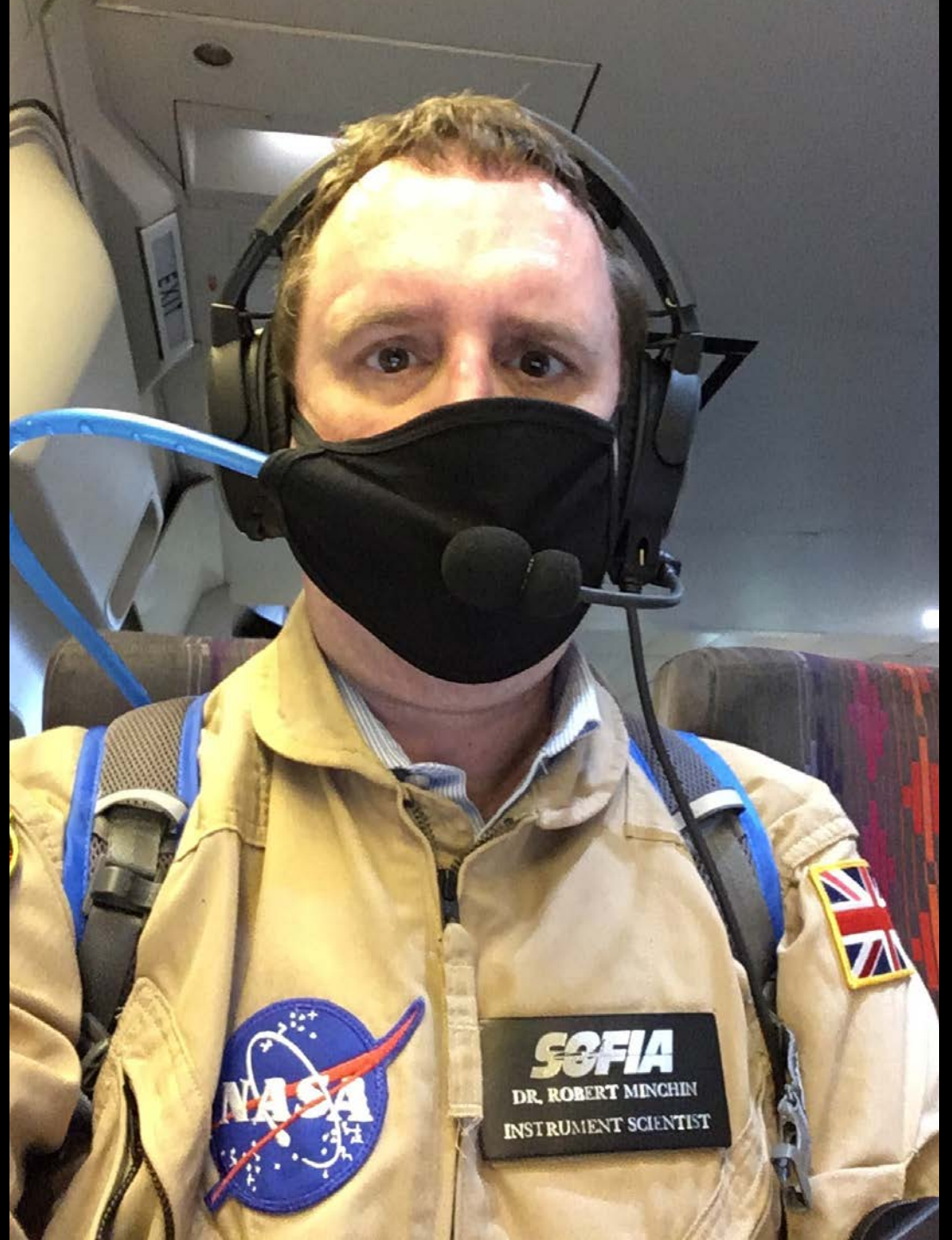
SOFIA Resumed Operations Under COVID-19 Protocols

In-Flight Science Mission Execution & Data Acquisition

SOFIA

"Some crew have started to use CamelBaks for easier hydration."

SOFIA Flash Report
Date: 2020-08-28 UT




SOFIA
HELIUM