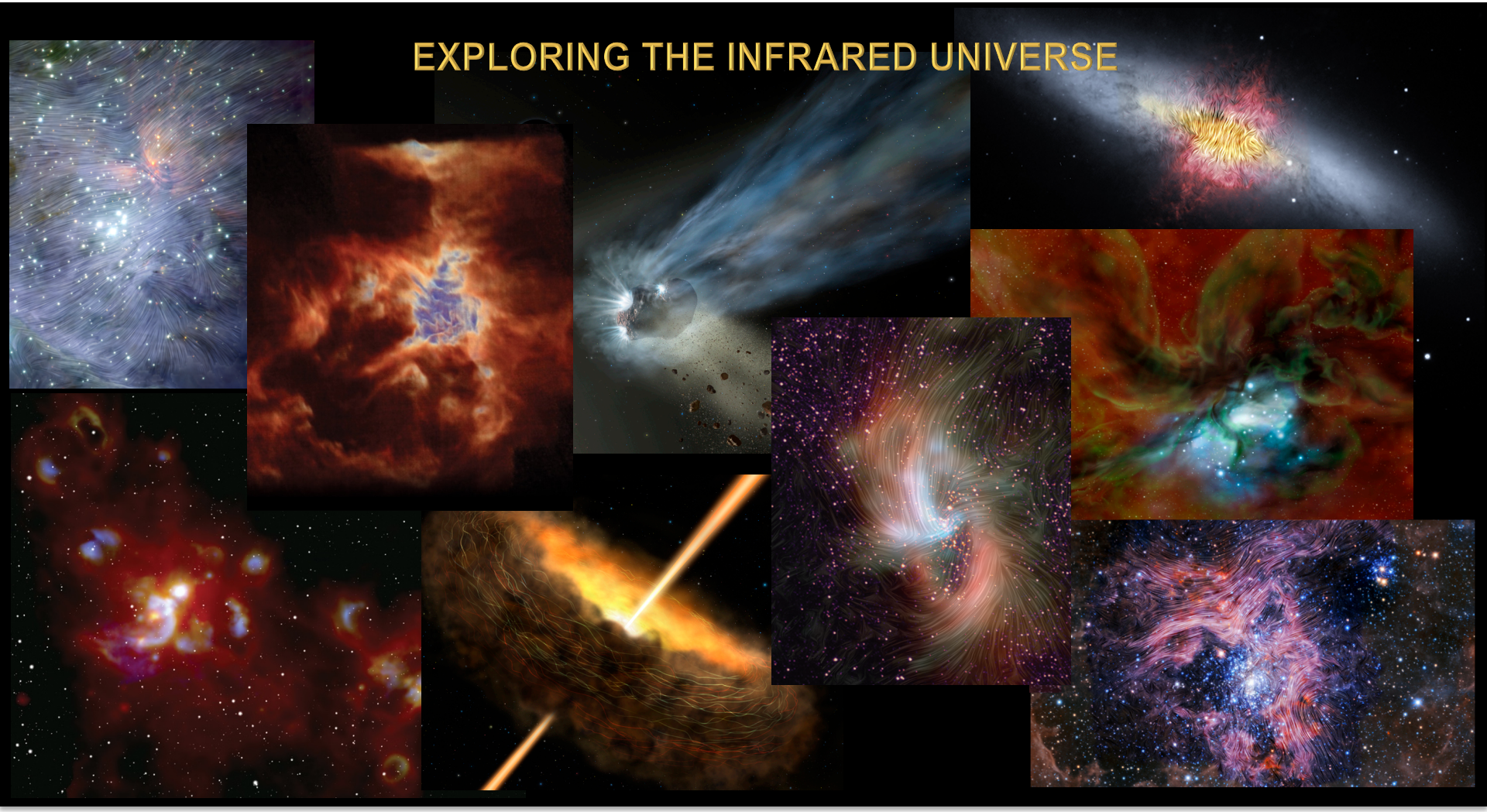
Response to FMR and SOMER Reviews

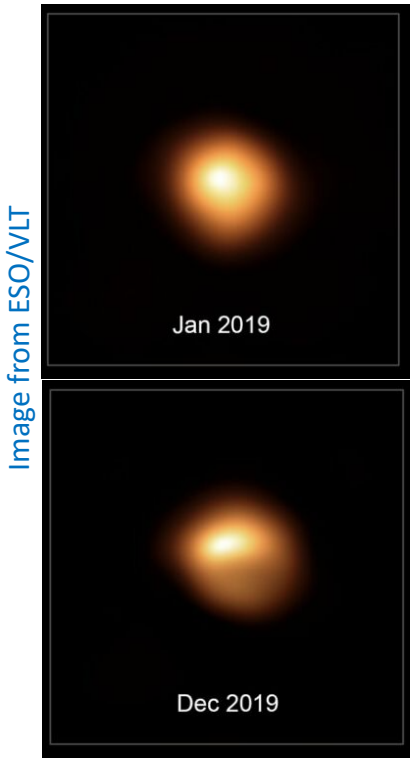


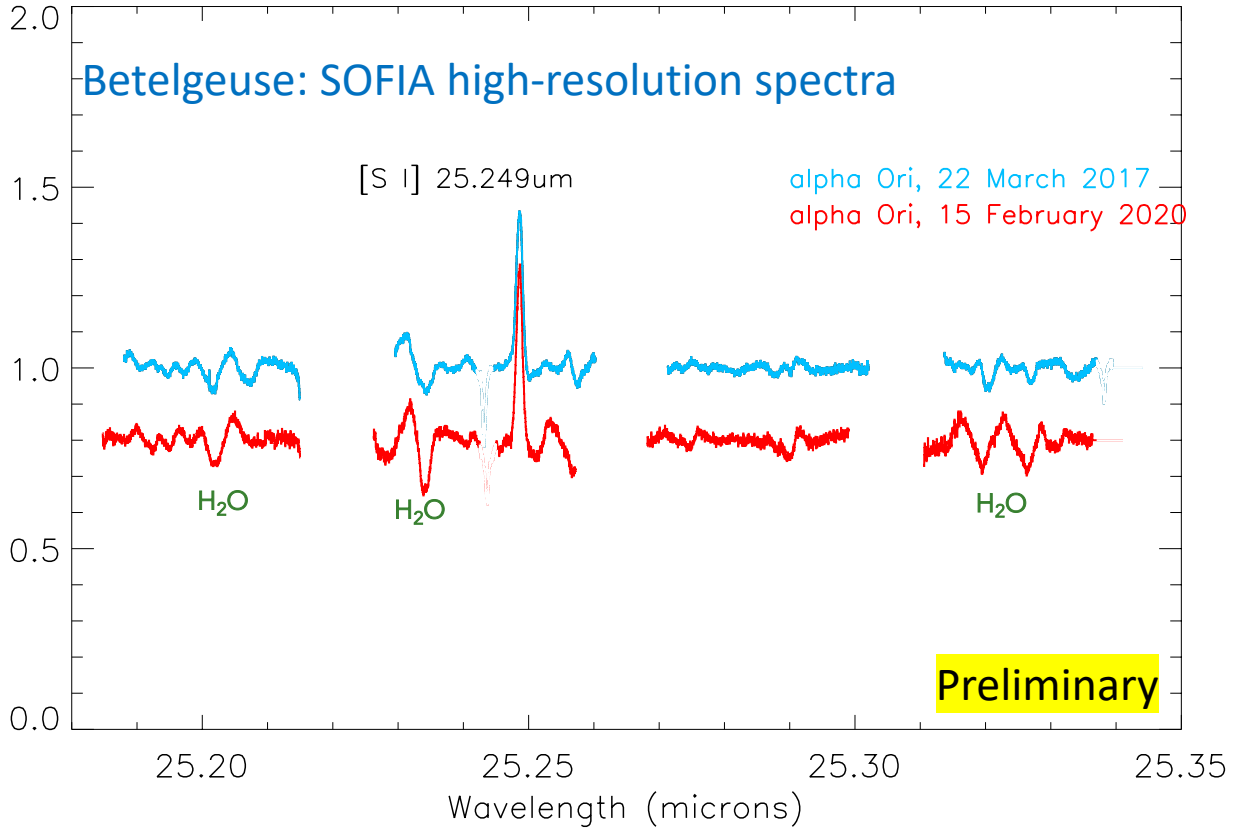
Naseem Rangwala, SOFIA Project Scientist
NASA Ames Research Center

Recent Highlights

Dimming of Betelgeuse: SOFIA investigates this Reg Supergiant

- SOFIA organized an observing campaign with 4 different instruments to observe and monitor Betelgeuse starting February to provide key scientific data to the community for understanding/studying the changes in this red supergiant.
- Study changes in the chemical composition and changes in the mid and far infrared fluxes. Two instruments have finished taking data and they are in process of being analyzed.
- Data become public immediately.
- SOFIA has engaged prominent scientists in this campaign for speedy release of key results from these observations.

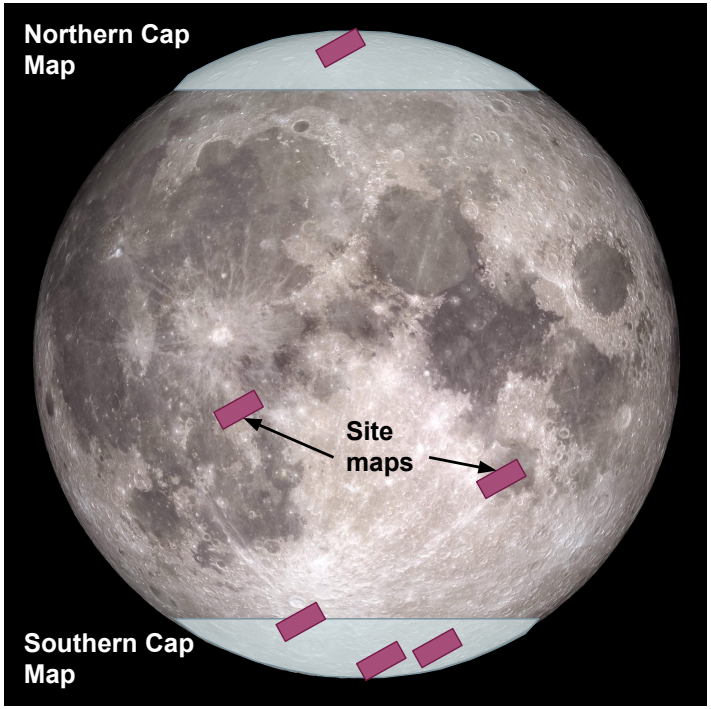




Recent Highlights

Mapping Water on the Moon
SOFIA Pilot Legacy Program

- SOFIA will map water on the Moon covering the polar regions and other key sites (scheduled for June).
- SOFIA is the only observatory that can provide remote access to the 6.1μm feature—a unique/unambiguous signature of water compared to previous 3μm observations from space.
- Provides key information to the NASA VIPER mission as this map covers all potential landing sites for the recently selected VIPER mission.
- Follow-up observations will provide more information about how easily water might be accessed by future missions, such as Artemis.
- These data become public immediately (Director's Discretionary Time observations).
- External dedicated science team is ready to investigate lunar "water cycle," how water is transported and sequestered across the Moon's surface.



Locations of potential SOFIA 6.1μm site maps on the lunar surface

Archival Funding Flash Call is planned to fund the community to pursue research with these data sets.

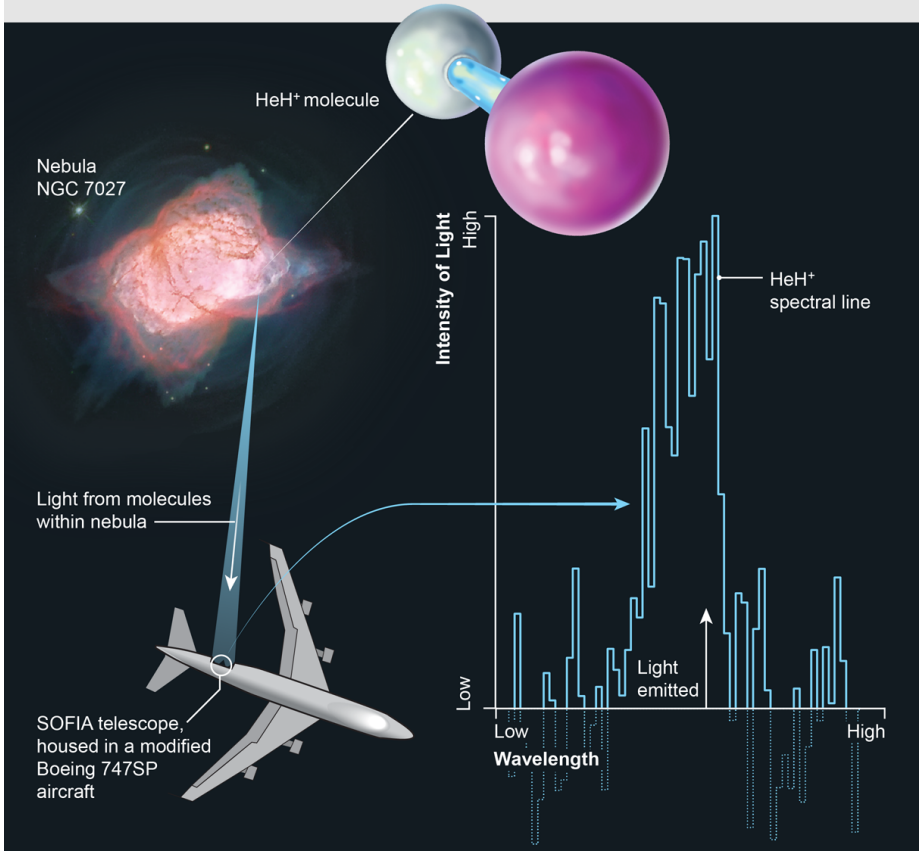
Changes Implemented Since the Reviews

- The Project made several changes to the Observatory, both in science implementation and operations, with the primary goal of substantially increasing scientific productivity and impact.
- All initiatives (implemented or in process of being implemented) are driven by science at the forefront.

1. Quality of Observing time, Quality of Science → Impact
2. Quantity of Observing time, Quantity of Science → Productivity
3. Efficiency

Scientific American Feb 2020: **The First Molecule In The Universe**

Astronomers identify molecules in space by observing their spectral features—the particular wavelengths of light they absorb and emit. Each molecule has a unique spectral signature based on its particular chemistry. Scientists first saw the signature of helium hydride (HeH^+) when they created this compound in Earth-based labs, and they predicted that it would have formed in the early universe. A long search for it in space finally paid off in 2016, when scientists spied this line in light coming from the nebula NGC 7027, using the Stratospheric Observatory for Infrared Astronomy (SOFIA), an infrared telescope mounted in a repurposed jumbo jet.



Changes Implemented Since the Reviews

Legacy Programs (Impact, Productivity, High-Quality Data):

- For Cycle 8 (starting April 2020), one legacy program (~80 hours) plus 4 pilot legacies were selected
- Roughly 25% of the total awarded time in Cycle-8
- Pilot legacies are both community- and observatory-led
- Goal is to have 33% to 50% of total time devoted to legacy programs (extension of pilot legacies to full legacies or selection of new legacies in Cycle 9)
- Enhances archival research

SOFIA Legacy Program: Mid-IR map of the Milky Way's central regions (observed July 2019; *Hankins et al.* 2020)
https://www.nasa.gov/feature/sofia-reveals-new-view-of-milky-way-center

Changes Implemented Since the Reviews

- Joint proposals – Aggressive pursuit of synergies with other Missions/Observatories (impact)
  - Collaboration with VIPER (scheduled)
  - Reserve time for JWST and ALMA proposals in Cycle-9 (in progress)
  - Joint call for proposals with GBT, IRTF and Gemini in Cycle-9 (in progress)
- Increasing high-quality data collection (impact, productivity, high-quality data)
  - Implemented shorter 8-hour flights in Cycle-8
  - Created more flight opportunities in Northern winter, when observing conditions are optimal (e.g., Single maintenance period)
  - Extended Southern Deployment using a new operations strategy
  - Implemented additional, more thorough technical review of the proposals in Cycle-8 to ensure that all scheduled observations are not only feasible, but are appropriately designed to produce publishable results
- Implemented a Different Operations Strategy for Southern Deployment (efficiency)
  - "Compressed 4" mode (4 flights, 2 days off, 4 flights, 2 days off…….)
  - Finish deployment faster
  - Single instrument deployment
  - 28 flights in ~7 weeks in Cycle-8 compared to 32 flights in ~9 weeks in Cycle-7

Changes Implemented Since the Reviews

- Implemented major initiatives to significantly improve efficiency, reduce staff stress, build robust mission operations (efficiency, high-quality data, productivity)
  - New mission prep tool to reduce pre-flight prep time from hours to minutes
  - Cross training of mission operations crew (in progress)
  - Refined flight planning tools to allow more accurate flight plans around restricted airspace
  - Automated weather update (36 and 12 hours) inbuilt into the flight planning tools
  - more instrument scientists / instrument

- Reduced time for instrument swaps creating more observing opportunities (productivity, efficiency)
  - Implemented and demonstrated for most of the instruments
  - Plan is to extend this to all instruments over the next few months

- Changed the policy for Priority-2 observing programs (productivity)
  - Priority-2 projects, once started, will be completed (effective Fall 2019)
  - Will boost program completion rate and publications

Changes to be Implemented in the near term

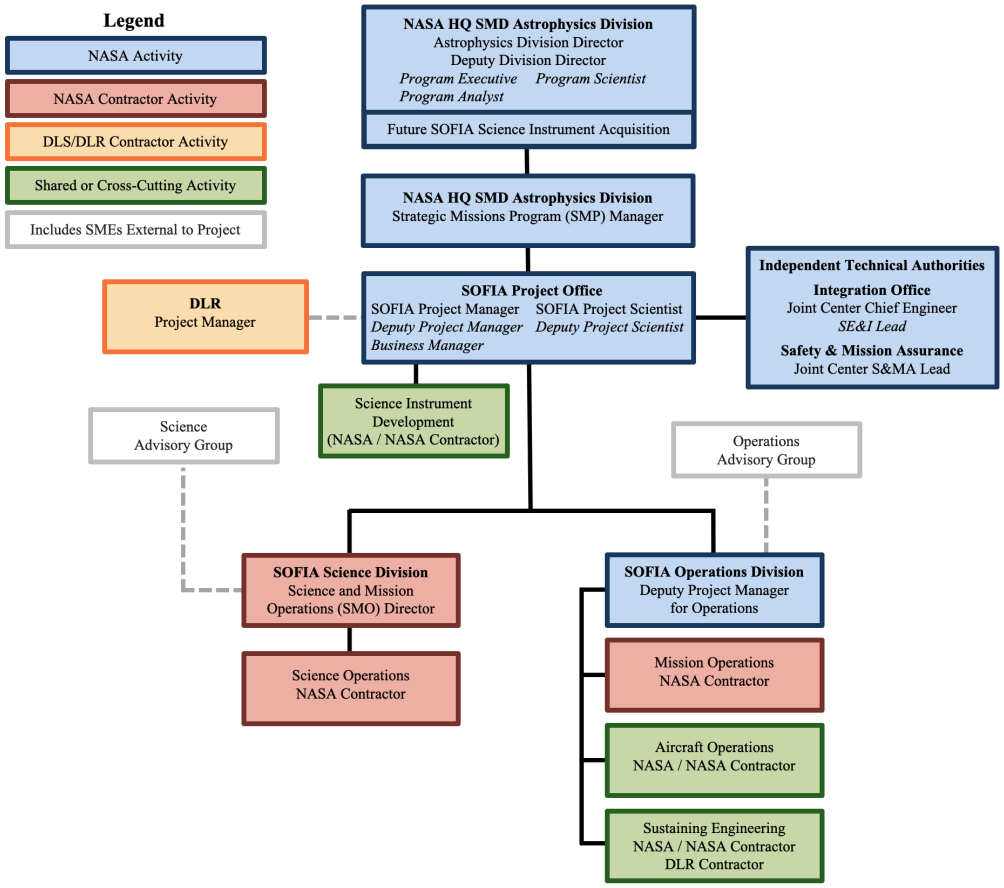
- Two-Year Observing Cycle (annual call)
  - Longer campaigns with a single instrument
  - Fewer instrument swaps
  - Greater scheduling flexibility
  - Higher program completion
  - Faster publication
  - High-quality data
- Joint Call for Proposals
  - Planning collaborations with the Green Bank Telescope, Gemini & IRTF due to our considerable scientific overlap
  - Planning to guarantee time for ALMA and JWST proposals
- Provide data faster to the community
  - If data are not archived within 15 working days, observers will be notified of the delay and the plan for getting it done
  - Data will be archived for each project as the projects are completed, rather than waiting for 100% of the data to be analyzed from an observing series
  - In the event of significant anticipated data processing delays, some preliminary form of the data is to be delivered to the observers
  - Improve Guest Observer program life-cycle support with a dedicated support scientist as the key point of contact

SOFIA Project Reorganization Fall 2019

SOFIA Project reorganized (as per NASA HQ guidance) to achieve sustainable operations model that is below the appropriated $85.2M to have the capability to use additional funds for augmentation for things like instrumentation, major development, flying more science flights, etc.

Sustainable operations model (under $85.2M) was achieved by:

- ~10% reduction in work force while:
  - maintaining staffing to operate the observatory at the cadence of 4 nights/week (5x8 in surge mode) and conduct annual Southern deployment
  - minimizing impact to science
- Project reduced to two divisions:
  - Science
  - Operations
- Observatory systems upgrades, sustaining and development engineering were cut:
  - consolidated under operations
  - reduced management overhead
  - no new spares; utilizing current stock
  - accepted risk to the availability and reliability of the Observatory to collect science as Observatory Systems failures will take longer to troubleshoot and fix with smaller team
- Science and mission operations also underwent a reorganization



Changes to be Implemented in the near term

Increasing time in the Southern Hemisphere

Historical data on SOFIA's Southern Hemisphere Observing Campaigns

	2013	2014	2015	2016	2017	2018	2019
Baseline Flights	9	0	17	24	24	25	32
Planned Take-Offs	9	0	17	25	27	26	32
Cancelled Flights			4	6	8	2	7
Actual Take-Offs	9	0	13	19	19	24	25
RTB (included in take-offs)			1	1	0	0	0
Dispatch Rate	100%	N/A	76%	76%	70%	92%	78%
Cancellation reason							
Weather			3		3	2	5
Mission Systems			1				2
A/C				1	5		
Engine				5			

- Cycle-8 NZ planned observing nights: 28 nights
  - New operations strategy: compressed schedule with more flights and single instrument
  - We will use lessons learned from this campaign to figure the most efficient way to further extend the Southern deployment
  - Southern deployment has historically produced ~1.5x more publications
  - Southern observing campaigns also cost ~1.5x more than the Northern ones

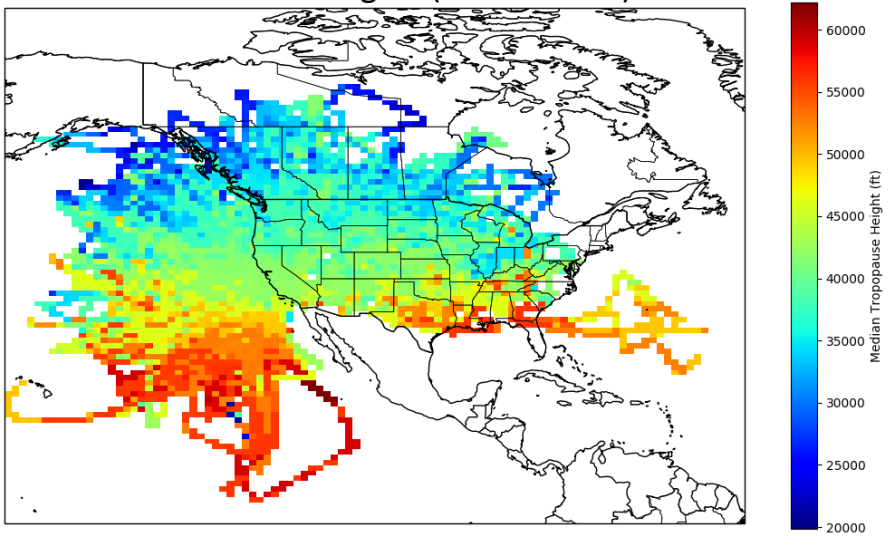
SOFIA Stratospheric Altitude & Water Vapor Analysis

Metric for High-Quality Observing Time

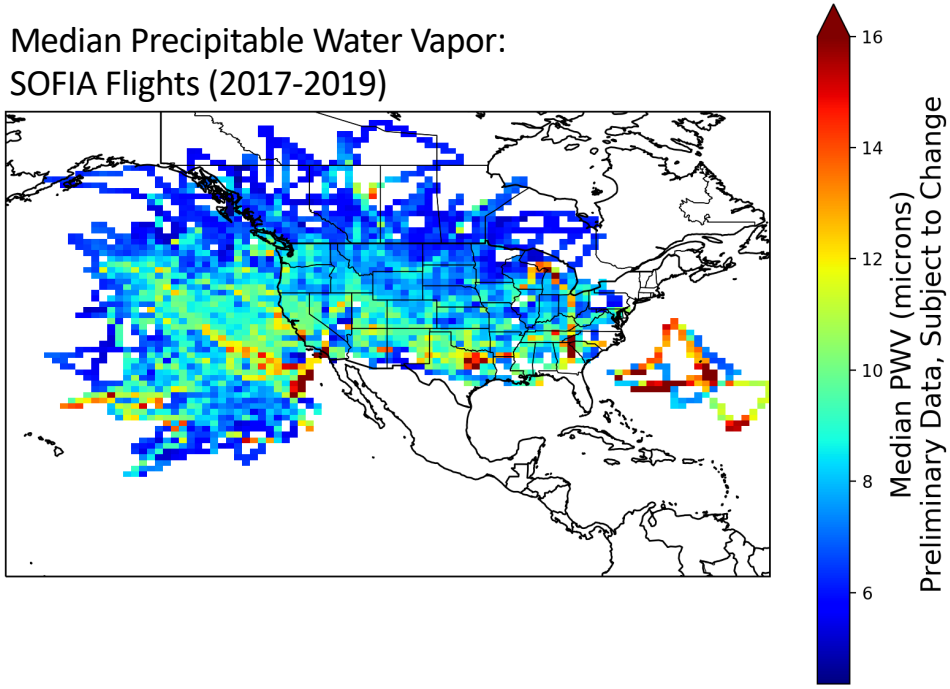
- Analysis using NASA GEOS weather database
- The flight path can cross tropopause multiple times
- Tropopause highly dependent on weather, location, time of the year
- Water vapor is the key parameter in determining data quality
- Water vapor map shows that even when below the tropopause, zenith water vapor can be low
- Initial results indicating that the weather may be the key factor for high water-vapor conditions

Preliminary Results

Median Tropopause Height:
SOFIA North America Flights (2015 – 2019)



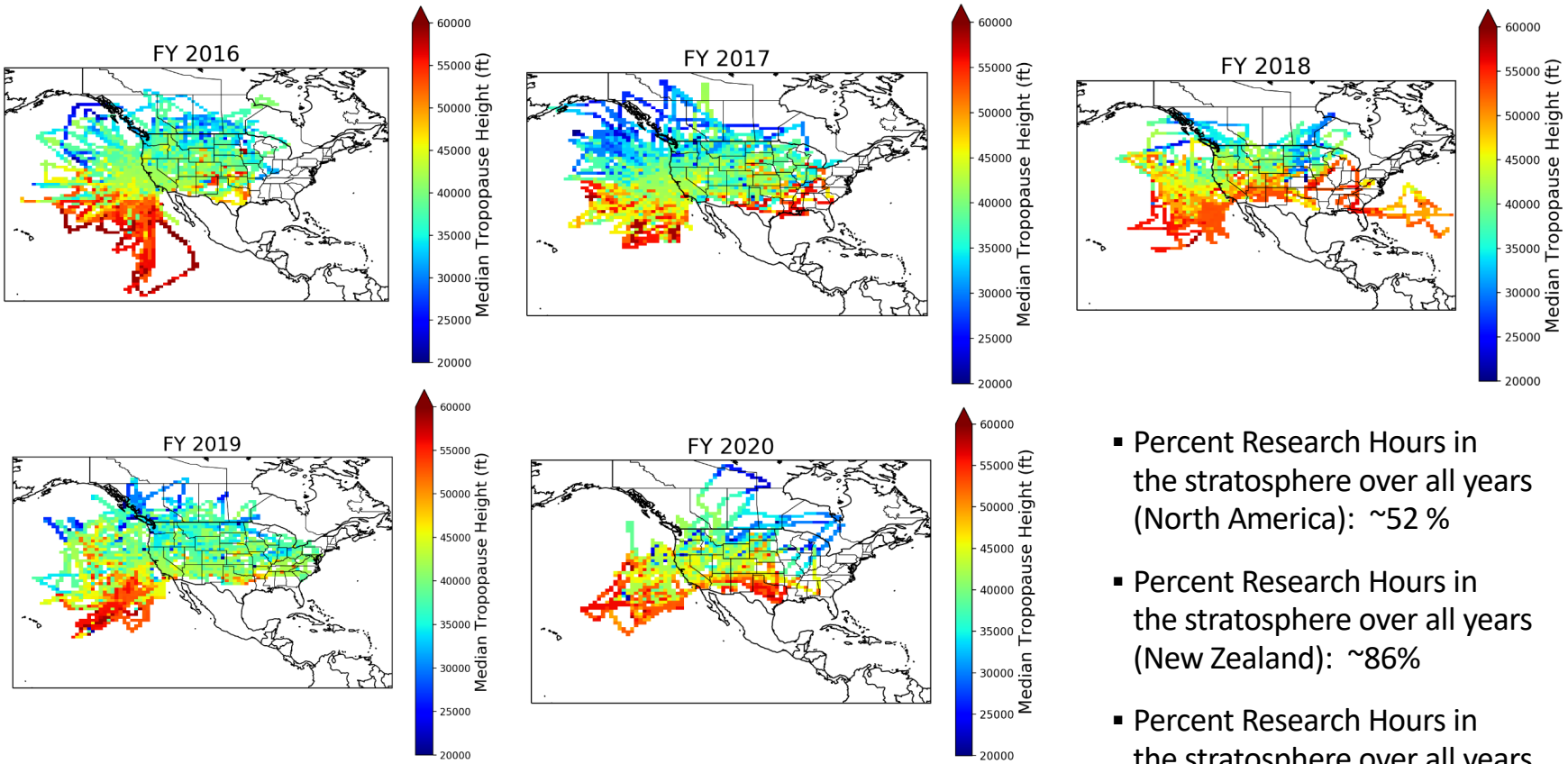
Median Precipitable Water Vapor:
SOFIA Flights (2017-2019)



Median Tropopause Height by Fiscal Year (FY)

North American Flights

Preliminary Results

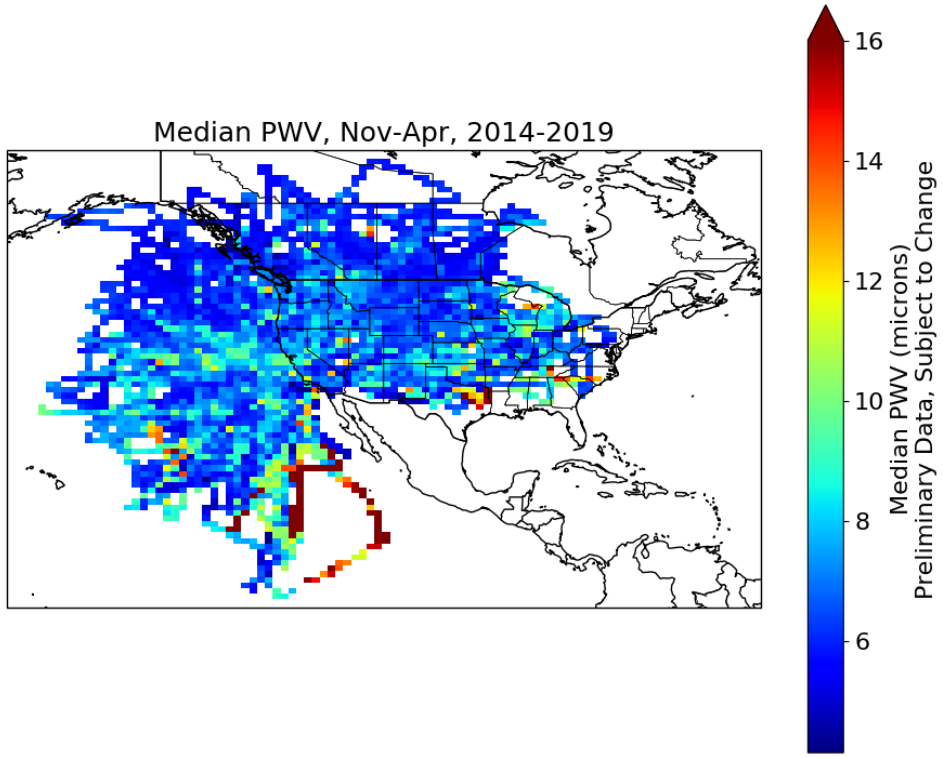


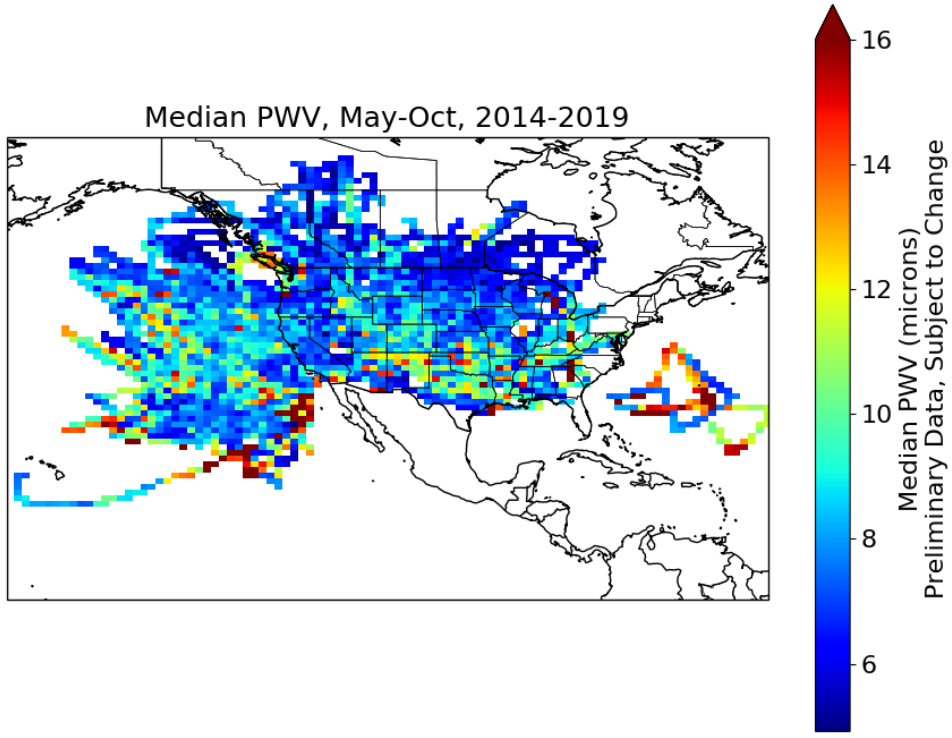
- Percent Research Hours in the stratosphere over all years (North America): ~52 %
- Percent Research Hours in the stratosphere over all years (New Zealand): ~86%
- Percent Research Hours in the stratosphere over all years (Winter Palmdale): ~70%

Median Precipitable Water Vapor (SOFIA North American flights)

Preliminary Results

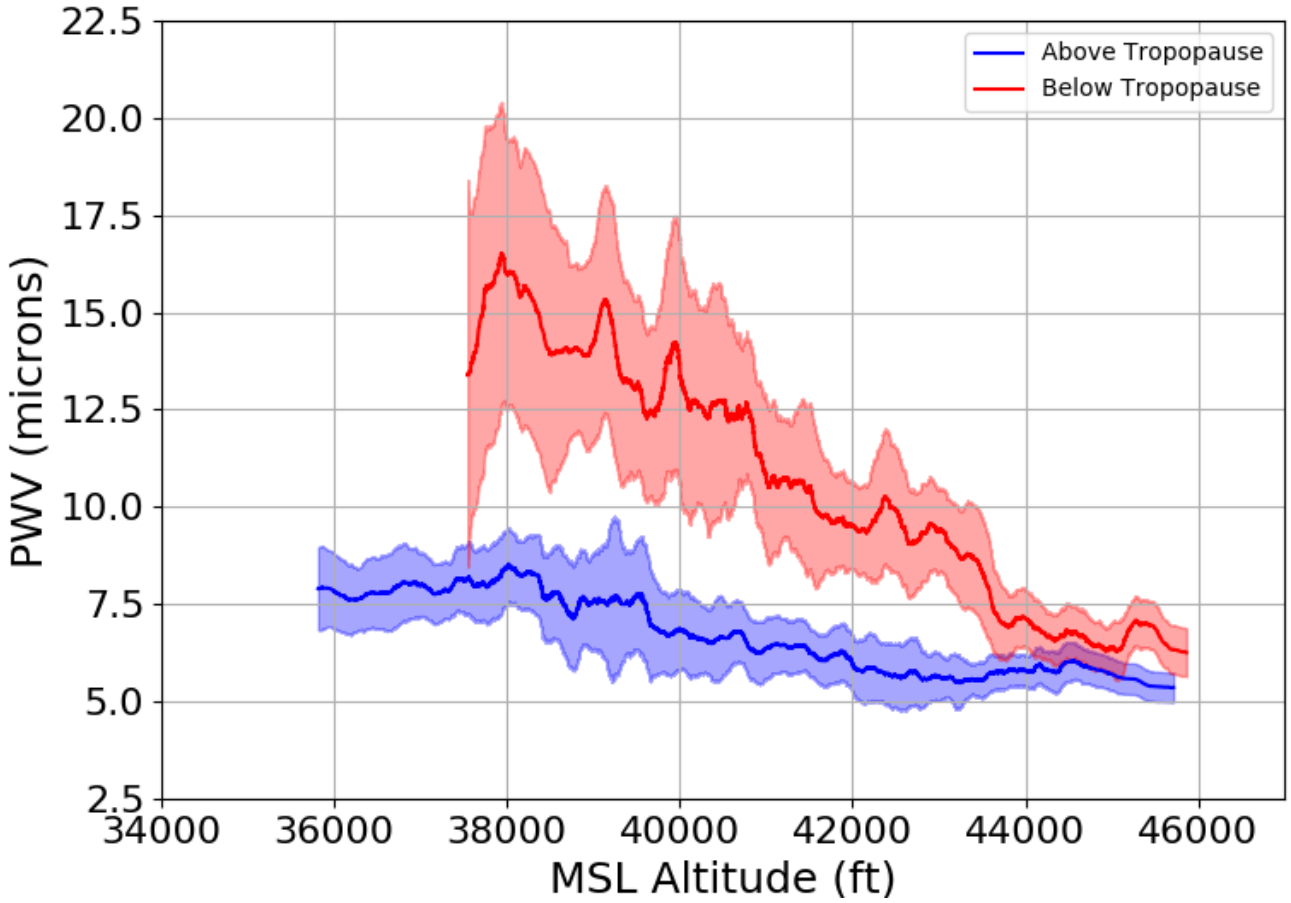
Seasonal variations in the water vapor between November – April and May – October for SOFIA flight between 2014 - 2019





Altitude versus Water Vapor (Observations from 2017 – 2019)

Median Scatter



Preliminary Results

Above 41,000 feet, whether in the Stratosphere or not, the observing conditions are optimal

Summary/Key Findings: SOFIA Stratospheric Altitude and Water vapor Analysis using NASA GEOS Weather data

- The NASA GEOS data base is potentially an excellent resource to calculate the tropopause height for SOFIA flights.
- The median tropopause height varies significantly with weather and location.
- The SOFIA flight path can cross the median tropopause several times during a flight even when flying at high altitudes (> 40,000 feet).
- The atmospheric water vapor content above SOFIA is a better metric to track data quality and can be measured using the same NASA GEOS database.
- Preliminary analysis shows that the water vapor can be low and optimal for SOFIA observations even when SOFIA is not technically in the stratosphere, which is determined using the median tropopause height as a binary switch.

Once the analysis is complete, the project can use this information to implement policies that will allow us to reschedule a flight or swap flight plans 12 to 24 hours before the mission when we get our weather update. If the water vapor is predicted to be high, such that the majority of the observing night will result in lower quality data, then the flight can be rescheduled or swapped with another flight path that is less impacted by weather. This analysis may also allow the Project to evaluate if specific instruments that require the best observing conditions should only be scheduled during certain times of the year regardless of proposal pressure during that time of the year.

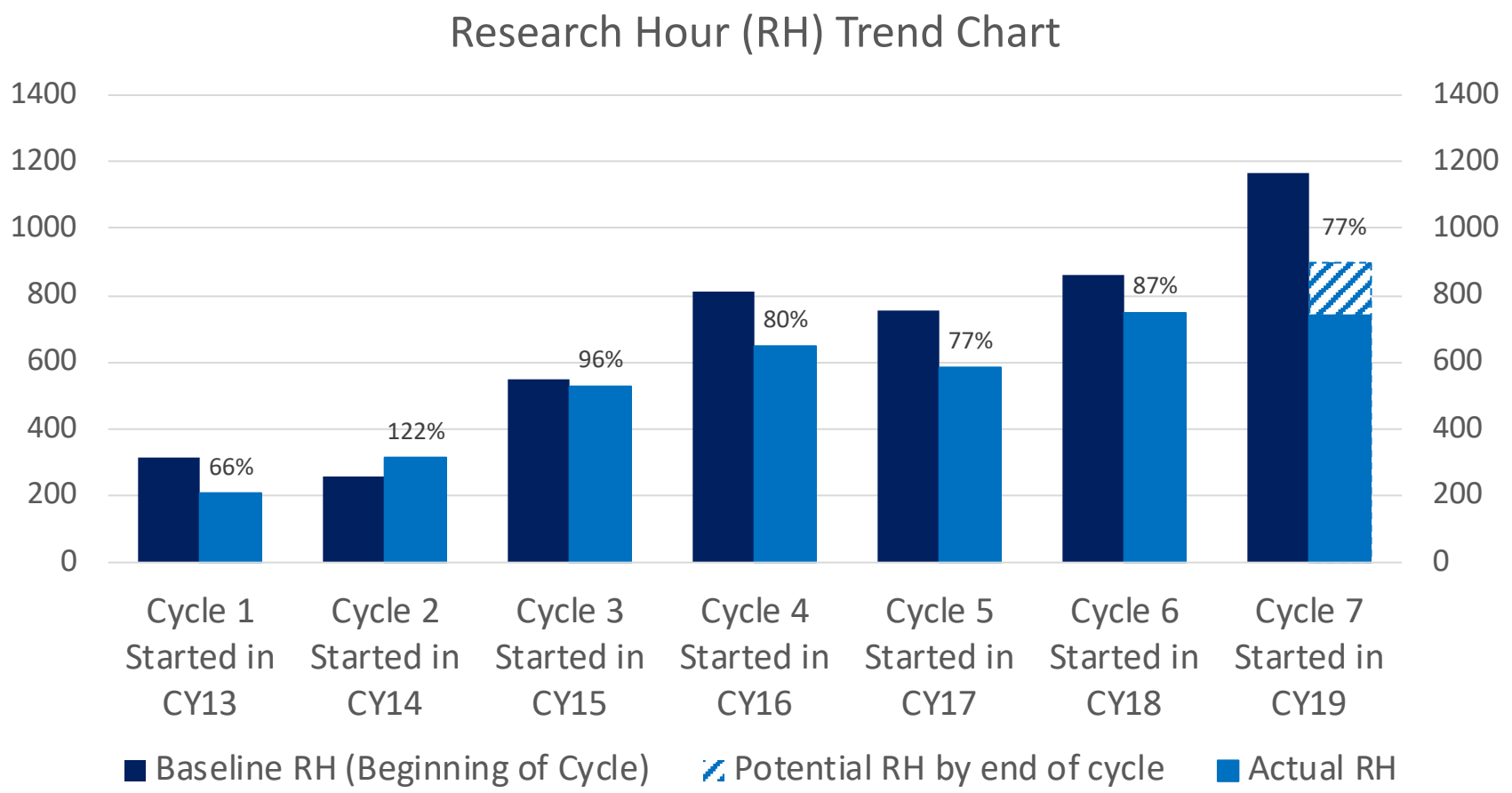
Response to Individual FMR and SOMER Recommendations

Metrics and Proposal Statistics

SOFIA

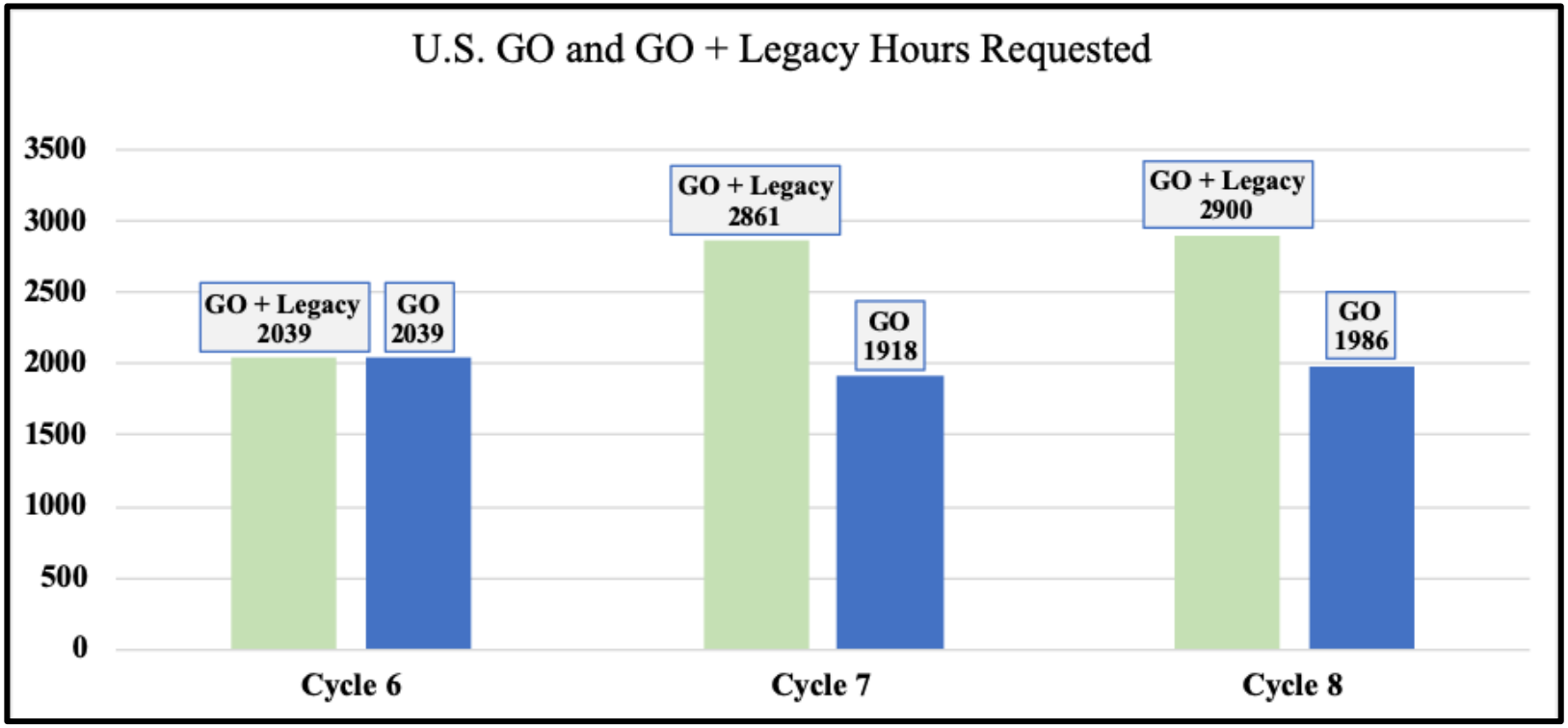
Stratospheric Observatory for Infrared Astronomy

SOFIA Research Hour Trends



Note: Cycle-6 baseline is adjusted for government shutdown

SOFIA Proposal statistics – hours requested

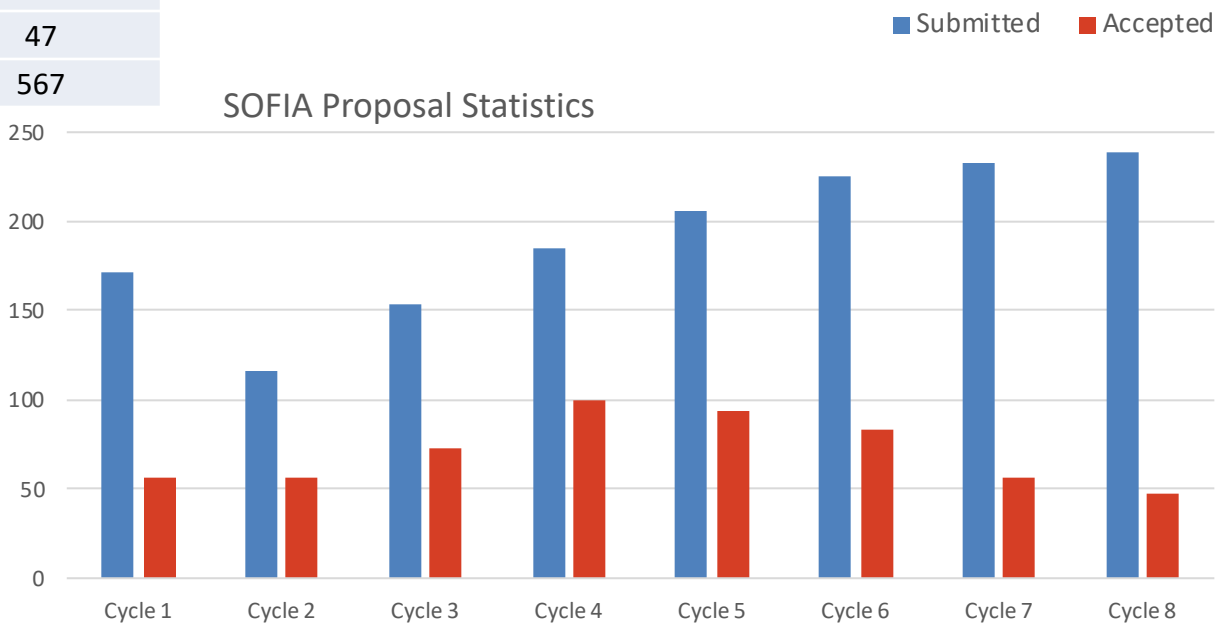


Cycle	Oversubscription (GO-only)	Oversubscription with Legacy and GO
8	6.6	5.8
7	4.8	5.7
6	4.1	4.1

Note: Legacy proposal category started in Cycle-7

SOFIA Observing Proposal Statistics – US GO queue only

Observing Cycle	Submitted	Accepted
Cycle 1	171	56
Cycle 2	116	57
Cycle 3	153	73
Cycle 4	185	100
Cycle 5	206	93
Cycle 6	226	84
Cycle 7	233	57
Cycle 8	238	47
Total	1528	567



Note: Starting Cycle-6, SOFIA started offering and selecting Legacy Programs that contribute substantially to the total awarded observing time. The decline in the number of accepted proposals starting Cy-6 is a reflection of this change. Cy-8 also have extended maintenance down time.

Note: Accepted Category include US plus Germany Priority 1 and Priority 2 proposals only

SELECT SCIENCE METRICS

Oversubscription Rate **(Goal: >5)**

Cycle	2	3	4	5	6	7	8
Oversubscription Rate	2.8	2.9	3	3.6	4	4.5	5.7

Note: Oversubscription rate from FOC to present

Metric (a)

Science Papers / Year

Table below presents science papers by year.

Science Papers/Year **(Goal: > 100 Papers/Year; includes paper based on SOFIA archive/yr > 30)**

FOC

	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
FORCAST	8	2	4	7	8	10	8.5	8	0	55.5
GREAT	19	0	2	12	7	11	11.5	11	0	73.5
FLITECAM *	0	0	0	1	0.5	0.5	0	0	0.5	2.5
HIPO *	0	1	0	1	0	0.5	0	0	0.5	3
EXES	0	0	0	1	1	1	7	6	0	16
FIFI-LS	0	0	0	0	0.5	0	5	2	0	7.5
HAWC_PLUS	0	0	0	0	0	0	4	5	1	10
Total	**27**	**3**	**6**	**22**	**17**	**23**	**36**	**32**	**2**	**168**

**HIPO and FLITECAM instruments decommissioned*
Note: Full Operational capability (FOC) in February 2014
Note: The fractions imply joint instrument paper

Metric (b)

Citations / Year

Table below presents the number of citations by year. **(Goal: H-index: 44;** current H-index = 22**)**

Date	8/8/17	3/28/18	9/4/18	1/28/19	3/18/19	11/13/19	1/15/20
Total Citations to All SOFIA Papers	750	855	1032	1175	1230	1512	1599

Metric (c)

SELECT SCIENCE METRICS

Completion Rate of High Priority Programs (Goal > 80%)

Table below presents the percent of total accepted proposals completed by observing cycle.

Percent of Total Accepted Proposals Completed by Observing Cycle

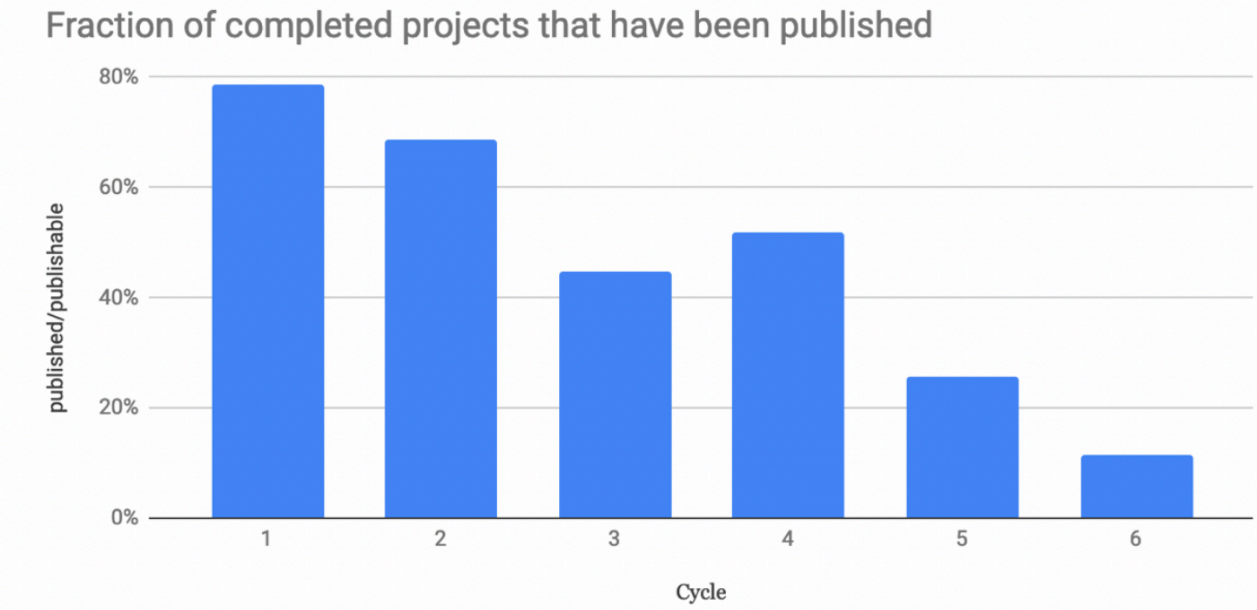
	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 6
Percent of total accepted proposals completed	63%	36%	42%	55%	64%

Notes:
Cycle 6 contained a government shutdown impacting the completion number.
Cycle 2 started in 2014.

Metric (d)

Current Cycle -7 completion rate ~ 75%

Fraction of High-Priority Programs Resulting in Publications (Goal > 80%)



Metric (e)

SMO Fiscal Year 20-21 initiatives mapped to FMR

Id	SMO Fiscal Year 20-21 Key Initiatives	FMR #
	Impact Driving Initiatives	
A	Prioritize Completion of Legacy Programs and Develop New Legacy Programs	3, 4, 10
B	Optimize Data Quality	2, 3, 4
C	Review the Proposal Selection and Evaluation Processes to Choose and Implement Projects That are Most Likely to Obtain the Highest Data Quality and to Be Completed Within the Cycle	1, 2, 3, 4, 10
D	Fly More Southern Hemisphere Flights	6
E	Create Science Focused Leadership and Functional Teams to Drive a Science Focused Culture	1, 2
F	Increase Science Time for Staff Scientists	1, 2
G	Strategic Instrument Planning	4
	Productivity Increasing Initiatives	
H	Improve Guest Observer Program Life-Cycle Support with a Dedicated “Friend of the Project” as the Key Point of Contact	2, 4
I	Review “Carry-Over” Policies Between Cycles to Boost Completion Rate	1, 2, 3, 4
J	Conversion and Optimization of Pipeline	4,7
K	Increase the Number of Post-Doctoral Scientists & Introduce Graduate Students	1, 2
L	Optimize Science Instrument Operations	3, 4, 7, 10
M	Strategic Partnerships with other Observatories	1, 4, 10

SMO Fiscal Year 20-21 initiatives mapped to FMR – cont.

	Efficiency Enhancing Initiatives	
N	Automate Repetitive and Rote Tasks Across Operations, especially Software	2, 4, 7, 10
O	Crosstrain Staff to Optimize Efficiency	2, 10
P	Send Delegations of Both Junior and Senior Staff to Successful Observatories and other Science User Facilities to Learn and Implement Best Practices	1, 2, 4
Q	Formalize Processes to Embrace and Evaluate Suggestions from the Staff	1, 2
R	Evaluate the "5 x 8" Model for Some Combinations of Instrument and the Time of Year, and if Optimal for Better Science, Implement a 5 x 8 Schedule	3, 4, 5
S	Integration and Inclusion of Key Personnel Across Science and Technical Concerns Regardless of Organizational Boundaries and Improvement of Processes	1, 2

Response to Individual FMR and SOMER Recommendations

Back-up Charts

SOFIA

Stratospheric Observatory for Infrared Astronomy

Response to FMR recommendations

FMR #1: *Nurture a science-driven culture within the mission*

- SMO reorganization completed
  - Underwent a transformation in its scientific management, through fundamental changes to its organizational roles and responsibilities (e.g., dedicated Associate Director for Research) to better align the staff's skills to the strategic priority of improving the scientific culture and the observatory's impact and productivity
  - Prepared a strategic plan (3-5 yrs and beyond) focused on productivity, impact and efficiency
- Postdocs/early career staff
  - More postdocs joined SOFIA since May 2019; SOFIA-only postdoc hiring ongoing (total number expected to be ~8 in the next few months)
  - Influx of new early career hires as visiting scientists/instrument scientists
- More opportunities to nurture a science-driven culture
  - Higher engagement and better communication with the SMO staff
    - Monthly scientists all-hands meetings to discuss and explore new ideas on a variety of topics related to scientific producitivty and community building.
    - Implemented a new staff suggestion scheme where every suggestion is reviewed by a committee of early- and mid-career staff and formally considered by senior leadership. These suggestions can be anonymous.

Response to FMR recommendations

FMR #2: *Embrace change. Identify and implement operational approaches that relieve staff stress, promote innovation, and increase science return*

- Larger fraction of awarded time devoted to Legacy programs in Cy-8
- Aggressive use of DDT (e.g., Betelgeuse Campaign, Water on Moon)
- Aggressive pursuit of synergies with NASA missions (e.g. VIPER)
  - Reserve time in Cy-9 for JWST and ALMA proposals (in progress)
  - Joint programs in Cy-9 with GBT, Gemini and IRTF (in progress)
- Immediate changes in current Cy-7
  - Complete priority-2 program that are started
  - 5 flights x 8-hour test week successfully completed and reported
- Changes in Cy-8
  - Implemented additional (thorough) technical evaluation to ensure high data-quality and high probability of publication
  - Implemented 8-hour flights
  - Extended Southern deployment with single instrument and different ops tempo
- New mission prep tool to reduce pre-flight prep time from hours to minutes
- Automated weather update (36 and 12 hours) inbuilt into the flight planning tools
- Reduced time for instrument swaps
  - Planning to implement this for all instruments (in progress)

Response to FMR recommendations

FMR #3: *Emphasize completion of high-priority science programs*

- In Cycle-6, the Project achieved its highest completion rate of 64%
- Revised policy to finish priority-2 programs once started
- Implemented an additional, more thorough technical review of the proposals to ensure that all scheduled observations are not only feasible but are appropriately designed to produce publishable results
- SMO Director will specifically evaluate and approve observations deemed high-risk/high-reward and can even increase the requested observing time to maximize the probability of mission success
- Two-year observing cycle (annual call) – discussions in progress for Cy-9 call for proposal

Response to FMR recommendations

FMR #4: Emphasize collection of high-quality data to increase science productivity and simplify post-observation data processing.

- Maximizing high-quality observing time
  - Implemented shorter 8-hour flights starting Cycle-8 in April 2020
  - Significantly Increasing Observing time in New Zealand (ongoing)
  - Increasing Observing Opportunities in (Palmdale) Northern Winter
  - Conducting detailed analysis (submitted in writing to the APAC) on measuring stratospheric hours and water vapor (above the plane) from NASA GEOS weather database to determine the right metric for high-quality observing time (ongoing)
- Conducting a robust proposal selection and technical evaluation process
- Prioritizing the collection of large, homogeneous data sets
- Exploring and implementing different operational modes for SOFIA to maximize observing time during the time of the year when observing conditions are optimal
  - Implemented a different operations strategy for Cy-8 Southern Hemisphere deployment

Response to FMR recommendations

FMR #5: Maximize observing time at stratospheric altitudes (typically above 40,000 feet) to get above water vapor and exploit SOFIA's unique observational capabilities.

- Maximizing high-quality observing time
  - Implemented shorter 8-hour flights starting Cycle-8 in April 2020
  - Significantly increasing observing time in New Zealand (ongoing)
  - Increasing observing opportunities in (Palmdale) Northern winter
  - Conducting detailed analysis (submitted in writing to the APAC) on measuring stratospheric hours and water vapor (above the plane) from NASA GEOS weather database to determine the right metric for high-quality observing time (ongoing)
  - Implemented a different operations strategy for Cy-8 Southern Hemisphere deployment

Response to FMR recommendations

FMR #6: Fly more southern hemisphere flights to increase scientific productivity.

- The Project has extended the Southern deployment in Cycle-8 from 24 to 28 flights.

- The Project in working on finding solutions to significantly extend Southern Deployment in Cycle-9/10 to $\gtrsim$ 35 flights.
  - This will require a different approach because a single long deployment was found to be extremely stressful on the SOFIA team in Cycle-7.

- In Cycle-8, the Project has implemented a new observing tempo of 4 flights, 2 days off, 4 flights, 2 days off……compared to the typical observing cadence of 4 flights, 3 days off, 4 flights, 3 days off……
  - This different observing tempo during the Southern Hemisphere deployment will compress the total amount of time spent in New Zealand and allow us to more quickly bring home our team.

- Lessons learned from Cy-8 deployment will be used to figure out solution for longer deployment in Cy-9/10, e.g. multiple back to back deployments with a break in between. This is an ongoing initiative.

Response to FMR recommendations

FMR #7: Transfer data products into the archive quickly and engage users in quality assessments

- If data are not archived within ‘15’ working days, observers will be notified of the delay and the plan for getting it done.
- Change in policy to archive data for each project as the projects are completed, rather than waiting for 100% of the data to be analyzed from the series.
- In the event of significant anticipated data processing delays, some preliminary form of the data is to be delivered to the observers.
- Guest observers will be sent a survey questionnaire when they are notified of their data product availability, in order to engage them in quality assessment.

Response to FMR recommendations

FMR #8: Adopt the SOMER recommendation to split aircraft operations from telescope/science operations.

- SOFIA carefully considered, and pursued, the development of a different management approach that would have separated aircraft flight and science operations.
- It was determined that this approach would not improve either our operational efficiency or scientific productivity nor would it realize cost savings.
- The central reason this new management approach would not be effective is simply due to the highly integrated nature of the SOFIA aircraft and observatory systems (Figure 1)
- SOFIA is an astronomical observatory that flies, incorporating telescope control and data networks as an integral part of the aircraft system. The maintenance, operations and cost of mission systems (i.e., observatory systems) that allow SOFIA to take scientific data could not be fully addressed by the reviews as they were outside the scope of their charters. The Project currently uses the same staff to maintain and operate both the aircraft and mission systems. Thus, separating the observatory's integrated functions into "only aircraft" and "only science", without adequately addressing the breakdown of the intermediate "mission systems", would likely increase inefficiencies and potentially the cost.
- Operations provided by an independent organization such as the Airborne Science Program was considered but aircraft and observatory are too integrated to have a clean separation and no organization was identified that could provide the support consistent with SOFIA's international requirements within cost and risk profile that SOFIA is using at this point in its mission
- The Project moved forward to implement changes to flight operations, science operations and the organizational structure based on the FMR and SOMER recommendations with the goal of substantially increasing the scientific productivity and impact of SOFIA.

Response to FMR recommendations

FMR #9: Invoke HIRMES cost and schedule control

- HIRMES development is continuing in FY 20
- HIRMES is in the Integration & Testing Phase since Dec 2019
- The HIRMES team and the SOFIA Project are working closely and have regular and open communications to track its progress
- The last HIRMES re-plan was in December 2018, when its cost and delivery date was renegotiated
- HIRMES cost to date is within the cost cap agreed to at the DPMP in early 2019
- HIRMES cost and schedule to complete will be reviewed following the completion of the current set of cool down tests
- If HIRMES is expected to exceed the Dec 2018 approved cost and schedule, then a continuation/termination decision will be made at that time
- The plan is to make HIRMES available to the community in Cy-10 and potentially in Cy-9 as shared-risk or through DDT

Response to FMR recommendations

FMR #10: Focus on science with current instruments (and HIRMES, if developed), not on post-HIRMES instrument development

- In the near-term, the SOFIA Project is primarily focused on significantly enhancing its scientific productivity and impact by prioritizing acquisition of high-quality science data with the current suite of instruments. In parallel, the completion of the HIRMES instrument development is also being pursued.

- The development of new science capabilities is one of SOFIA's strongest features, and in the long run, the observatory plans to develop new cutting-edge instrumentation and upgrades to existing instruments based on community input. By developing and deploying the newest technology, the SOFIA observatory will remain fresh and vibrant, with the flexibility to adjust to new science discoveries, new science priorities, and guaranteeing continued robust interest from the science community.

SOFIA summary

- NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) is operated and maintained by NASA's Ames Research Center (ARC) and Armstrong Flight Research Center (AFRC). The Science Division is at ARC and the Operations Division is with the plane in Palmdale, California. The project reached Full Operational Capability (FOC) in February of 2014.
- After 5 years of operations, the NASA Science Mission Directorate (SMD) established the SOFIA Operations and Maintenance Efficiency Review (SOMER).
- At its inception in 1996 until 2019, SOFIA was its own Program and in 2019 it transitioned to a Project by direction from the NASA's Science Mission Directorate, Astrophysics Strategic Missions Program (ASMP).

Management Recommendation 1

Divide SOFIA program into two independent projects

- SOFIA carefully considered, and pursued, the development of a different management approach that would have separated aircraft flight and science operations.
- It was determined that this approach would not improve either our operational efficiency or scientific productivity nor would it realize cost savings.
- The central reason this new management approach would not be effective is simply due to the highly integrated nature of the SOFIA aircraft and observatory systems (Figure 1)
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- Operations provided by an independent organization such as the Airborne Science Program was considered but aircraft and observatory are too integrated to have a clean separation and no organization was identified that could provide the support consistent with SOFIA's international requirements within cost and risk profile that SOFIA is using at this point in its mission
- The Project moved forward to implement changes to flight operations, science operations and the organizational structure based on the FMR and SOMER recommendations with the goal of substantially increasing the scientific productivity and impact of SOFIA.

Management Recommendation 1-continued

Divide SOFIA program into two independent projects

- The SOFIA Program has been reorganized into a Project with two major divisions: Science and Operations
  - Operations provided by an independent organization such as the Airborne Science Program was considered but aircraft and observatory are too integrated to have a clean separation and no organization was identified that could provide the support consistent with SOFIA's international requirements within cost and risk profile that SOFIA is using at this point in its mission
  - The SOFIA Operations Division will be responsible for flight and ground operations, aircraft and observatory maintenance and sustaining engineering
  - The SOFIA Science Division will be responsible for science selection, science and mission operations, data pipeline, data delivery and science outreach

- Upgrades and Development work (except for HIRMES) will be minimized in the near-term as the Project focusing on enhancing science productivity with the current suite of instruments

Management Recommendation 2

Government-Owned Contractor-Operator (GOCO)

Consider issuing an RFI to determine the feasibility of an external entity operating the 747SP as a GOCO research platform on behalf of NASA

- SOFIA started with operations provide by a GOCO (United Airlines) but this mode failed for several reasons and the Program took over operations.
  - Science and aircraft operations are intermingled and difficult to separate
- Given that the Project is now in extended mission, it will re-examine the issue. RFI will go out in 2021 to request interest and approximate costs of operating and maintaining the entire SOFIA observatory
  - Operations primary facility location would be identified but estimate would include southern hemisphere operations
- An RFP would be generated to coordinate selection with the current contractor contract option schedule if there is positive response from the RFI

Management Recommendation 3

Metrics

Re-establish firm operational metrics and measure performance against them regularly

- SOFIA has been using metrics to track performance since operations began and are posted and reported regularly (80 metrics are defined of which 4 are for operations).
- The complexity of SOFIA operations makes tracking single items (departure time, cancelled flights, etc.) difficult to assess the impact on science observations
  - Cancelling a flight may only partially impact observations that require more than one flight and observations may be completed on subsequent or contingency flights
- Several operational performance metrics have been clarified to allow better interpretation of the metric information
  - Platform Dispatch Rate
  - Observatory Utilization Efficiency
- The Project will review metrics with its stakeholders with each observing cycle

Operations Recommendations 4 & 5

6-Flight week of 8-hour Flights

Shorten flights to 8-hours, allowing quicker access to the stratosphere, shorter duty days for the team, and more hours in a day for maintenance and fly 6 days a week

- Changing from four 10-hour flights per week (the current baseline) to six 8-hour flights a week would require significant increase in staff, especially in non-aircraft staff which were not considered by the SOMER review
- A test was conducted last fall by flying a week five 8-hour flights using the HAWC+ instrument
  - Results supported that five 8-hour flights may be more advantageous when operating in May through November at Palmdale and has been implemented in Cy-8
- Shorter flights provide less time to cool the mirror to low temperatures which may affect some observation plans
- Risks that will be tracked as five 8-hour flights/week operations are implemented include staff fatigue, impacts of deferred maintenance on schedule, and crew hour limitations

5 day x 8 hour flight cadence

5x8 Response to the SOMER & FMR panel recommendations

- In September and October 2019, SOFIA SMO executed a demonstration test of flying 5 days 8 hours each to determine effects of such a cadence and whether it provides a benefit to science and can be supported by the staff.
- The test successfully demonstrated
  - the ability to reach the stratosphere more quickly on 8-hour flights
  - The atmospheric opacity was lower at the higher altitudes.
- Ability to fly either weekly cadences of 4 flights of 10 hours duration or 5 flights of 8 hours duration varies:
  - Flight Crew mission operators could support either option on the surge basis (not sustained operations
  - Would have to add 2 pilots and additional mission ops crew to sustain 5x8
  - An extra flight launch and recovery each week significantly adds to the workload of ground support staff and impacts pilots
- Shorter flights do not necessarily allow for more maintenance time between flights
- The primary and secondary mirror temperatures are on the average colder on longer flights, therefore providing some signal to noise benefit on the longer flights.

5 day x 8 hour flight cadence

5x8 Response (Continued)

- The quality of SOFIA data depends on seasonal and astronomical factors; as well as which science instrument, wavelength, and observing mode is used – with each object having its own "equation" to determine optimum science observation.
- Research indicated what time of the year 8-hr or 10-hr flights are better for each location as summarized below:
  - In Christchurch, NZ - 10-hr flights are always best
  - In Palmdale, CA –
    - From Dec – Apr, 10-hr flights are best; and on average equivalent to flights in Christchurch, NZ
    - **In May /June and Oct/Nov, 8-hr flights are better than 10-hr flights. The Project has implemented 8-hour flights in cycle-8**
    - In July – Sep, neither 8-hr or 10-hr flights will reach the stratosphere. During these months SOFIA will deploy to New Zealand and will reserve time for annual maintenance.
- The main conclusion is that the Project can support and provide 5x8 cadence on a surge basis using using the current staffing when requested by the science center.

Operations Recommendation 6

Shorten Crew Duty Day

Reduce duty day (shortening mission briefings, pre- and post-flight briefings)

- All briefings have been reviewed for required agenda items and attendance
- After detailed review, the pre-flight timeline has been reduced from 3.0 to 2.5 hours since mid-April.
- There has been no impact to safety but also no significant cost savings and increased risk of finding an issue that can't be fixed without impacting the mission in the shortened time
- A serious attempt was made to reduce the duty day from 13 hours to 12 hours, which could allow flight crews to fly more often in a given week, but the risk of operating with essentially no schedule margin was considered too high and has not been implemented

Operations Recommendation 7

Minimize Instrument Swaps

Minimizing Instrument swaps reduces down-time and allows for more observation time.

- Moving to 2-year observing cycles will dramatically reduce instrument swaps (in progress)
- Spending larger fraction of observing on Legacy Programs will also reduce the number of swaps

Operations Recommendation 8

Dedicated Aircrew

SOFIA should use 3 dedicated aircrews and retain one part-time crew for reserve

- A dedicated crew plan can be implemented, but will carry with it a risk of greatly increased cost, increased training costs due to high turnover rates, and a general decline in skill level of SOFIA aircrew, potentially affecting not only mission accomplishment but flight safety as well.
  - A dedicated flight crew will have greater difficulty covering outages and periods of attrition.
  - SOFIA currently has 12 part-time flight crew members that allows schedule shifts when needed to cover individual extended outages; this might not be possible with dedicated crews.
  - Additional hires would be required at AFRC to replace part-time staff and to perform ancillary activities that the flight crew now does (including training).
  - Salary competitiveness would incur noticeable risk that staff would not stay long or would be less qualified than desired.
  - Part-time crews enjoy the opportunity to fly multiple aircraft types while only charging to SOFIA while working for SOFIA, reducing need for simulator work and reducing "burn out" resulting in higher turnover.
  - However, the Project does believe that hiring a full-time replacement chief pilot will be beneficial and is currently in the process of doing so.

Operations Recommendation 9

DLR Exchange Crew

Incorporate exchange DLR aircrew to support flight operations to benefit from DLR's extensive operational experience

- The Project would consider using DLR aircrew if their aircrew met all requirements and costs of using the DLR aircrew were minimal
- Currently NASA does not have the budget or staff available to provide crew for DLR aircraft and it's not clear they would get much return given that they already fly multiple aircraft types on multiple mission types

Workforce Recommendation 10

Reduce full-time Operations & Maintenance workforce

Reduce/reassign full-time Operations and Maintenance workforce in in the areas of inspectors, operations engineers, logistics, and flight safety; decreasing extraneous costs. Review the downtime for annual maintenance to see if the number of observing weeks could be increased.

- Based on these specific recommendations, SOFIA has eliminated 7 full-time positions and is considering further reductions.
  - The requirement to maintain the aircraft and instruments 7 days a week over multiple shifts, implementing all of the specific reductions recommended was not possible.
  - Some of the reductions are possible because of an agreed upon increase in risk posture for non-safety related activities.
- Observatory systems, sustaining and development engineering staff have been dramatically reduced and consolidated under operations, including reducing the management overhead.
  - No new spares; utilizing current stock
  - all new development work is being discontinued
- The project has recognized that C-checks are not required annually given the number of flight hours that are being flown, so the project will plan for shorter annual maintenance checks starting in 2021