Concept of Operations Stratospheric Observatory for Infrared Astronomy (SOFIA)

Level 1
SOF-DA-PLA-PM17-2000

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SOFIA Concept of Operations

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NASA/Pamela Marcum, Project Scientist	02/10/2014 Date

Revision History

REV	DATE	DESCRIPTION	APPROVAL
-	05-1998	Original Version developed and released by USRA.	
-	10-2005	Updated to reflect program office change (from ARC to AFRC) for SMOR review	
-	06-2011	Updated to divide into Level 1 and Level 2	
-	01-10-14	New baseline established for NASA-Managed SOFIA Program (PRG-CCR-148) A change log for the 12 December 2013 draft version have been posted on the SOFIA Confluence wiki: http://dfvmsofia.ndc.nasa.gov:8090/display/ConOpsL1/Level-1+Concept+of+Operations	PMB

TABLE OF CONTENTS

FIGURES

APPENDICES

1 BASIS OF OPERATIONS

The Stratospheric Observatory For Infrared Astronomy (SOFIA) Concept of Operations (ConOps) is built upon the initial Design Reference Mission (DRM) (USRA-DAL-SSMOC-SCOP-REP-5300B) that illustrated the scientific potential of the Observatory. As discoveries in the field of astrophysics and advances in observing technology have created new applications for SOFIA, additional mission case studies have been written and posted on the SOFIA website (www.sofia.usra.edu/science). The Science Vision for SOFIA (USRA-DAL-SSMOC-SCIN-REP-1018) highlights key science questions that will be addressed. These prototypical scenarios were used to develop the initial operating concept of SOFIA.

Figure 1: SOFIA Aircraft

SOFIA's science promise and basis of operations:

- Offers astronomers a unique platform with regular access to the entire mid-infrared/far-infrared wavelength range of the electromagnetic spectrum.
- Provides an opportunity for training instrumentalists and developing new technologies required for future infrared instrumentation via a science instrument (SI) program that allows for new instruments and upgrades to existing instruments (a white paper by Erickson et al., SOF-AR-MEM-OP01-2005).
- Serves as an opportunity for scientific exploration by educators and for attracting new generations of scientists and engineers through a combination of vigorous Outreach programs (Education and STEM Engagement: Education Plan, SOF-US-PLA-PM09-2002; Public Engagement & Public Affairs: Communications Plan, SOF-US-PLA-PM09-2001).

1.1 Observatory Description

The SOFIA Program is a cooperative effort between the National Aeronautics and Space Administration (NASA) and the German Aerospace Center (DLR) to obtain data to better understand the nature and evolution of the universe; the origin and evolution of galaxies, stars, and planetary systems; as well as conditions that led to the origins of life. Through frequent flight missions in the Earth's stratosphere where the view to space is largely unobstructed, SOFIA provides astronomers routine access to the infrared and sub-millimeter part of the electromagnetic spectrum.

SOFIA (or 'the Observatory' or 'the Airborne Observatory') consists of a uniquely modified Boeing 747SP aircraft and a 2.5-meter effective aperture gyro-stabilized Telescope Assembly (TA) integrated with a science instrument (SI). Primary components of the Observatory System onboard the aircraft are depicted in Figure 2.

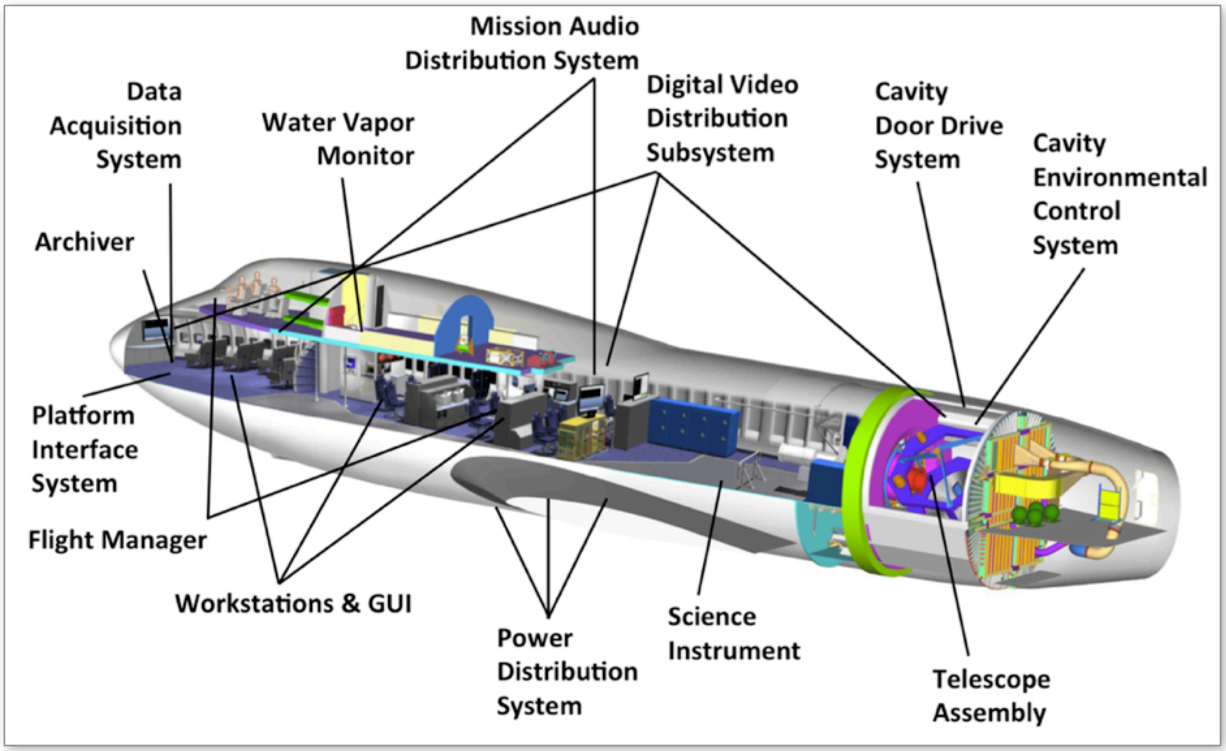

Figure 2: SOFIA Observatory System

The telescope views astronomical objects through a large articulating open port in the upper left-hand quadrant of the aircraft fuselage aft of the wing. A pressure bulkhead separates the unpressurized telescope optics compartment from the forward passenger cabin; the telescope extends through this pressure barrier with the SI mounted in the pressurized passenger section, providing hands-on access to SI teams. The pressurized section also contains the Mission Controls and Communications System (MCCS) that maintains observation requirements, in combination with aircraft flight-path management, through integrated movement of the telescope and articulating port.

The Observatory includes related Ground Support Facilities (GSF), Ground Systems, and Ground Support Equipment (GSE).

1.2 Document Scope

This Level-1 Concept of Operations (ConOps) document describes NASA's and DLR's plan for operating SOFIA and conducting all science and mission operations once the Observatory is completed, verified and validated, and has reached its Full Operational Capability (FOC). As defined in the NASA HQ Science Mission Directorate (SMD) Program Commitment Agreement (PCA) (SOF-HQ-PD-PM91-0001), FOC is reached when the Observatory has demonstrated full science operational capability with four available science instruments (SIs). The NASA/DLR Joint SOFIA Program Plan (SOF-DF-PLA-SOF-1005.2) provides information specific to the NASA and DLR roles and responsibilities during the operations phase.

The purpose of this document is to give the reader a high-level understanding of the planning and implementation of the Program operational elements that will result in the best science value within the planned budget for SOFIA. Planning and implementation includes management of science operations, aircraft and flight operations, science mission operations, engineering and maintenance, and education and public engagement. A Level-2 ConOps (SOF-DA-PLA-PM17-2077) is in development to provide additional detail.

The SOFIA Work Breakdown Structure (WBS) Dictionary (SOF-DA-WBS-PM24-2001) details the operational elements for the Observatory. For ease of reference, definitions for key operational elements are presented below:

Science Operations
The Science Operations (SciOps) element includes the managing, directing, and controlling of the science investigation aspects, as well as leading, managing, and performing the technology demonstration elements of the Program. Specific responsibilities include defining the science or demonstration requirements; prioritization of Science Targets, ensuring the integration of these requirements with the science instruments and Observatory; ground systems, and mission operations; providing the algorithms for data processing and analyses; and performing data analysis and archiving. This element includes the management of the Guest Investigator (GI) program. This element excludes responsibility for hardware and software for on-board science investigative instruments.

Science Mission Operations
The Science Mission Operations (MOPS) element covers the management of the development and implementation of personnel, procedures, documentation and training required to conduct science mission operations. This element includes the receiving and processing of telemetry data, monitoring and analyses of observatory system status, flight path planning and monitoring, and mission planning for and operation of the Telescope Assembly for target acquisition and pointing. It includes maintenance, repair, checkout, calibration, operation and logistical support for all aircraft, science and mission systems on the observatory and in the SSC/SOC, whether on the ground or in flight from local or remote bases.

Aircraft Operations
Aircraft Operations (AOPS) operational element includes the integrated Aircraft System and TA that serves as the platform for carrying science instrument(s), humans, and other mission-oriented equipment to the mission destination(s) to achieve the mission objectives. The Observatory System includes the basic aircraft subsystems as appropriate: Crew, Power, Command & Data Handling, Telecommunications, Mechanical, Thermal, Propulsion, Guidance Navigation and Control, Wiring Harness, and Flight Software. This element also includes all design, development, production, assembly, test efforts and associated Ground Support

Equipment to deliver the completed system for integration with the Science Instruments. This element does not include integration and test with Science Instruments and other project systems.

Flight Operations
Flight Operations begins with pre-flight activities, which are typically conducted within 24 hours of a science flight. The Science Mission Operations (MOPS) team finalizes the mission plan and associated data, then transfers the flight datasets to the aircraft. The MOPS group then verifies the mission systems are properly configured for flight, including any science instrument onboard. Aircraft Operations files the finalized flight plan with the Federal Aviation Administration (FAA) and performs pre-flight checks, fueling, and towing of the SOFIA aircraft. Once the aircraft is airborne, the MOPS team leads the science data collection, with support from Science Operations to operate the Facility-class Science Instrument (FSI) or the PI team to operate a Principal Investigator-class Instrument (PSI). Aircraft Operations is responsible for piloting the aircraft safely through the in-flight operations. Once the aircraft has landed, the MOPS team is responsible for transferring all flight data off the aircraft. The Aircraft Operations group tows the aircraft back to the hangar and performs post-flight checks.

Airborne Operations
Airborne Operations includes Flight Operations and all in-flight activities related to Aircraft Operations, Science Operations, and Mission Operations. The Airborne Operations work element excludes ground-based activities for Aircraft Operations, Science Operations and Mission Operations.

Engineering and Maintenance
Engineering and Maintenance operational element encompasses the specialized engineering tasks associated with general periodic maintenance, as well as supporting specialized engineering tasks for issues that may arise. Engineering and Maintenance is responsible for SI Labs and Pre-Flight Integration Facility management. SI receiving and processing, SI installation, and removal from the TA, TAAS operations, TA optics maintenance and cleaning, the Mirror Coating Facility, and assisting the German partner with TA engineering and maintenance.

Education and Public Engagement
Engaging and alerting the public regarding mission activities and achievements via channels such as mission public websites, social media postings and broadcasts, podcasts, Google+ "hangouts", and also public talks and exhibits. Generally occurs outside of formal and informal educational settings. [NASA HQ Offices of Communication & Education have changed the name of "Public Outreach" to "Public Engagement." In response to government-wide spending cuts, NASA's STEM (Science, Technology, Engineering, and Mathematics) educational programs may be re-defined in FY2014].

SOFIA Science and Mission Operations
The SOFIA Science and Mission Operations (SSMO) work element is managed by a contractor based at the SOFIA Science Center (SSC). The contractor for this work element is called the "SSMO" throughout this document. The SSMO is responsible for the development and maintenance of science and mission operations systems and facilities at both the SOFIA Science Center (SSC) and the Science Operations Center (SOC). The SSMO is responsible for all activities, procurements, and manpower associated with the development and execution of the integrated plan and systems for bringing the SSMO into operation. This element includes the development of the Mirror Coating Facility (MCF), mission facilities, science laboratories, simulation facilities and network infrastructure. This element includes development of the

science flight planning software; the development of the Data Cycle System (DCS) software and hardware, including the data archive hardware; the development of the Data Processing System (DPS); the simulation labs; the information systems infrastructure; the move, re-installation and re-commissioning of the MCF.

1.3 Document Organization

The SOFIA Level-1 Concept of Operations document is organized into four major sections:

1. Basis of Operations
2. System Overview
3. Operational Overview
4. Operational Phases

The Operational Phases section is the main body of the document describing operations from early planning to program disposal. It consists of the following seven phases:

1. Observatory Planning
2. Observatory Certification and Commissioning
3. Flight Series Preparation
4. Science Mission Operations
5. Post-Flight Activities
6. Planned Maintenance
7. End-of-Program Disposal

The interactions among the major operational groups are described in an integrated manner in each of the above phases.

1.4 References

Document Number	Title	Date / Revision
NASA-DLR AGREEMENTS		
--	NASA/DLR MOA	2006
SOF-DF-PLA-SOF-1005.2	NASA/DLR Joint SOFIA Program Plan Part II	Jan 2012
NASA HQ SMD COMMITMENT AGREEMENT		
SOF-HQ-PD-PM91-0001	Program Commitment Agreement	Oct 2010
PROGRAM PLAN		
SOF-DF-PLA-PM01-1000	Program Plan	2014*
SAFETY PLANS		
SOF-DF-PLA-SOF-1086	Safety and Mission Assurance Plan	Apr 2007
APP-DF-PLA-PM22-2000	Airborne Platform System Safety Plan	Apr 2011
SOF-DF-PLA-OP05-2000	Program Mishap Preparedness & Contingency Plan	Jun 2013
CONCEPT OF OPERATIONS		
SOF-AR-PLA-PM17-2000	Level-1 Concept of Operations	Dec 2013
SOF-DA-PLA-PM17-2077	Level-2 Concept of Operations	2014*
WORK BREAKDOWN STRUCTURE		
SOF-DA-WBS-PM24-2001	WBS Dictionary	Oct 2010
AIRBORNE OPERATIONS		
DOP-O-300	Aircrew Flight Operations Manual	Oct 2007

Document Number	Title	Date / Revision
APP-DF-PLA-PM23-2000	Airborne Platform Logistics Plan	Feb 2009
AFRC-354	NASA AFRC/Air Force MOA, Plant 42 Airfield	Sep 2009
APP-DF-PLA-PM01-2004	Platform Project Maintenance Plan	Dec 2009
SOF-DF-PLA-PM17-2002	Flight Requirements for Non-Essential Aircrew	Apr 2010
DCP-O-002	Aircraft Work Order Procedure	Sep 2011
SCIENCE MISSION OPERATIONS		
SCI-US-PLA-PM17-001	Science and Mission Operations Plan	Oct 1998
USRA-DAL-SSMOC-SCOP-PLAN-5200	Science Operations Calibration Plan	Dec 2006
USRA-DAL-SSMOC-SCOP-REP-5300B	Design Reference Mission (DRM)	Feb 2007
SOF-DF-PLA-SOF-1087	Science Utilization Policies of the SOFIA	Jan 2008
SOF-DA-PRE-PM91-2079	SSMOR II Presentation	Feb 2008
USRA-DAL-SSMOC-SCIN-REP-1018	Science Vision for SOFIA	May 2009
SOF-AR-MEM-OP01-2005	Training of Instrumentalists & Dev. of New Tech.	2009
SOF-AR-PLA-PM01-2005	SOFIA Observatory Policies	Jan 2013
DATA MANAGEMENT		
SOF-DF-PLA-PM03-2009	Program Data Management Plan	Jul 2010
SOF-DF-DEF-PM91-2022	SOFIA Records Retention Schedule	Jun 2013
USRA-DAL-1162-00 Rev A	Science Data Management Plan	2014*
USRA-DAL-SSMOC-SCOP-PLAN-5500	SOFIA Pipeline Project Management Plan	Aug 2012
SYSTEMS ENGINEERING AND INTEGRATION		
SOF-DF-PLA-PM02-1064	Systems Engineering Management Plan	Feb 2010
SOF-DF-PLA-PM91-1068B	Program Risk Management Plan	Feb 2010
SOF-AR-PLA-PM91-2021	Program Information Technology Plan	Aug 2012
SOF-DF-SPE-SE01-068J	SOFIA Specification Tree	Apr 2013
SCI-US-ICD-SE03-2023E	ICD for the Data Cycle System	Mar 2013
SOF-1030	Systems Interface Requirements Specification	Jun 2001
CONFIGURATION MANAGEMENT		
SOF-DF-PLA-PM03-1054	Program Configuration Management Plan	Dec 2011
APP-DF-PLA-PM03-2006	Airborne Platform Configuration Management Plan	Mar 2007
SCI-AR-PLA-PM03-2001	Science Configuration Management Plan	Jul 2008
SCIENCE INSTRUMENTS		
SCI-AR-MEM-PM12-2019	SI Re-scoping Process	Apr 2010
SOF-AR-SPE-SE01-2028	SI System Specification	Apr 2011
SCI-AR-HBK-OP03-2000	SI Developers' Handbook	Jun 2011
SCI-US-PLA-PM17-2010A	SI Data Processing Plan	Jun 2011
SCI-US-PLA-PM17-2065	FSI Maintenance Plan	Jun 2012
SCI-US-PRO-OP02-2077	HIPO Science Instrument Installation Procedure	Apr 2013

EDUCATION AND PUBLIC ENGAGEMENT		
SOF-US-PLA-PM09-2001	Public Engagement & Public Affairs: Communications Plan	2014*

Document Number	Title	Date / Revision
SOF-US-PLA-PM09-2002	Education and STEM Engagement: Education Plan	2014*
SOFIA LEXICON		
SOF-DF-PD-2009	Lexicon	Aug 2013
DEPLOYMENT GUIDES		
APP-DF-HBK-OP02-2100	Deployment Guide - Germany	Nov 2011
SOF-AR-HBK-OP02-2176	Deployment Guide - Southern Hemisphere - NZ	Jul 2013
LESSONS LEARNED		
APR-7120.6	Lessons-Learned Process	2014*

* In the process of being updated; estimated date of completion is 2014

2 SYSTEM OVERVIEW

2.1 System Scope

SOFIA is designed to make sensitive measurements of a wide range of astronomical objects at wavelengths from 0.3 to 1600 μm . This observatory is a key element in astronomical research for chemical and dynamical studies of warm material in the universe and for observations of deeply embedded sources and transient events.

SOFIA's flight lifetime and time-frame (Figure 2) will make it the premier facility for performing far-IR and sub-millimeter wave astronomy from 2010 until the mid 2030s. It will be the only facility available for wavelength coverage in the 28-1200 μm spectral region and for high resolution spectroscopy during much of that period

Because of its unique operational capabilities, SOFIA will be a test bed for new technologies and a training ground for a new generation of instrumentalists and astronomers. SOFIA is capable of continual upgrades and can be used to evaluate state-of-the-art and high-risk technologies that could otherwise only be proven in space.

The SOFIA science program will cover a long time period, so SOFIA observations will be complemented by data from present facilities such as Hubble Space Telescope (HST), Chandra, Spitzer, AKARI, ALMA, WISE, and Herschel and future facilities such as James Webb Space Telescope (JWST), SPICA, and SAFIR.

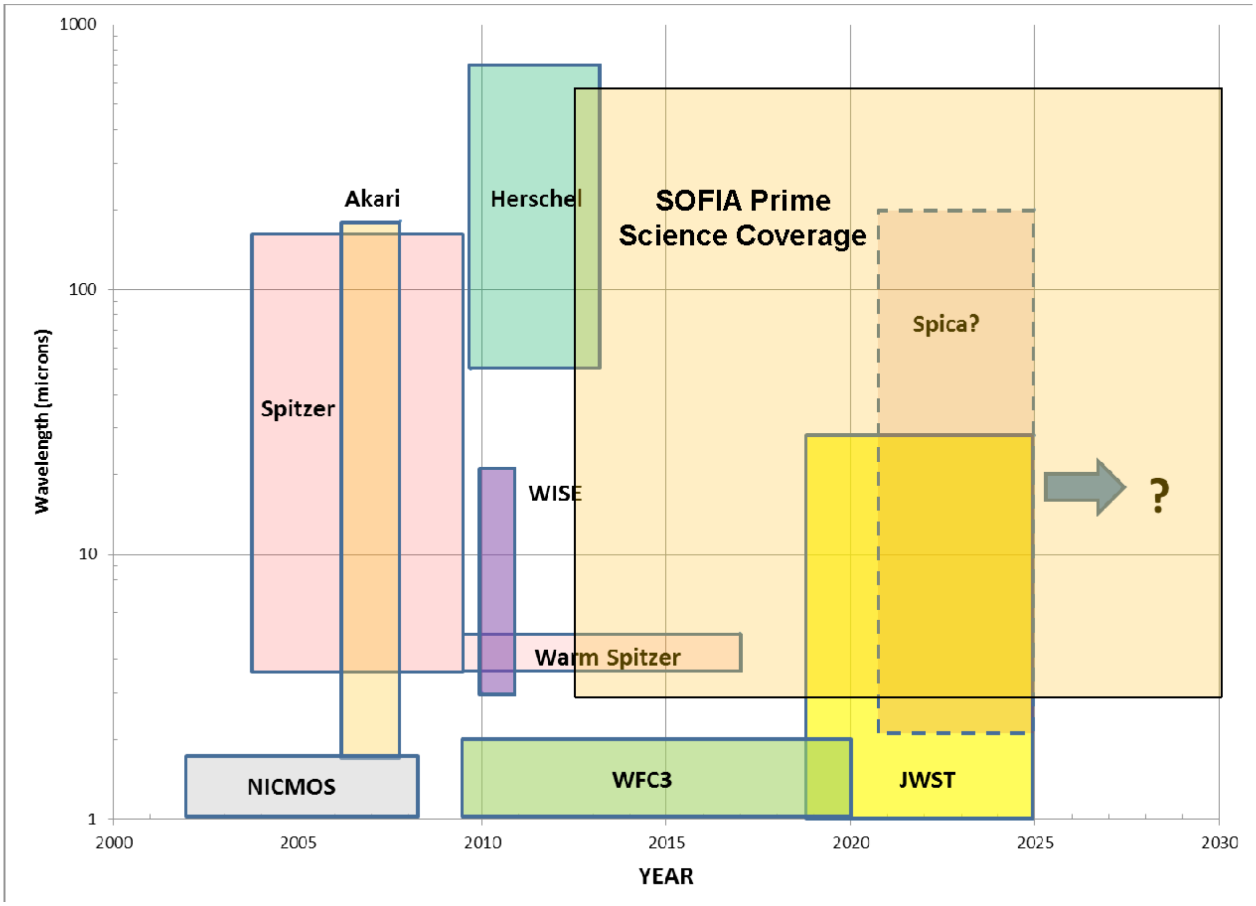

Figure 3: Infrared Capabilities During Flight Lifetime

Generally, SOFIA excels at those observations that demand some combination of good mid- and/or far-infrared atmospheric transmission, reasonably high spatial resolution, very high spectral resolution, and/or the ability to rapidly deploy to a specific location on the Earth. In particular SOFIA will be a powerful probe for understanding the physics and chemistry of a wide variety of astronomical objects, ranging from solar system objects to distant galaxies.

2.2 System Goals and Objectives

The primary goal of the SOFIA program is to further scientific knowledge in the field of astronomy and astrophysics by complementing and augmenting ground- and space-based observation capabilities through development and operation of a next-generation airborne observatory. Specifically, SOFIA program objectives are to provide science investigators with a system having approximately nine times greater sensitivity, three times better angular resolution, and observations of compact sources in a volume of the universe 30 times greater than the respective capabilities of its predecessor, the Kuiper Airborne Observatory (KAO).

With nearly full access to the infrared and sub-millimeter parts of the electromagnetic spectrum available from observation in the stratosphere, SOFIA will investigate interstellar cloud physics and stellar birth in our galaxy, proto-planetary disks and planet formation in nearby star systems, and the origin and evolution of biogenic atoms, molecules and solids, amongst other phenomena. As such, the goals and objectives of the SOFIA program are directly aligned with NASA’s Strategic Plan.

In addition to its wide range of expected scientific contributions, SOFIA promotes and supports both state-of-the-art and advanced focal plane and instrumentation technologies and also provides extensive scientific community involvement in support of future space astronomy missions. SOFIA promotes attainment of U.S. and German goals for the improvement of science, technology, engineering, and mathematics, education and literacy through a concerted and broad set of Outreach efforts (Education, STEM Engagement, Public Engagement, and Public Affairs).

As an airborne observatory that is deployed throughout the world, another key goal of the SOFIA program is a first principle commitment to safety throughout its entire life cycle; i.e., *constant attention to safety is the cornerstone upon which NASA builds mission success*. Simply stated, this first principle is embodied in the following hierarchy: 1) safety of the flight crew, other occupants of the observatory, and the general public is the top priority; 2) protection of the physical flight assets is the second priority; and 3) science mission data is the third priority, as it can be acquired on another flight on another day.

System Goals:

- Conduct safe operations for 20 years beginning at FOC
- Successfully support 40 distinct observing programs and their associated science teams per one-year observing period
- Perform 120 science flights within a one-year period to obtain 960 science research-hour requirement
- Capable of supporting the integration and commissioning of one new science instrument every 24 to 36 months.
- Provide science data for General Investigators and the broader science community of a quality suitable for newsworthy scientific results and publication in peer-reviewed astronomical journals.
- Provide Education and Communication programs that make use of SOFIA's unique and inspirational attributes as an airborne observatory.

2.3 Users

The principal customers for SOFIA are the U.S., German, and other international astronomy communities, as together they represent the ultimate users of the observatory in conducting scientific investigations.

Therefore, the principal system's users are the qualified astronomers who answer calls for observation proposals and are selected as General Investigators, the Principle Investigators who build SIs and are allocated observing time.

The U.S. observing proposal call will be open to all qualified astronomers, including instrument teams and SOFIA staff scientists. Exemptions for German proposers are specified in the NASA/DLR Joint SOFIA Program Plan (SOF-DF-PLA-SOF-1005.2) and the SOFIA Observatory Policies document (SOF-AR-PLA-PM01-2005).

Observing time on SOFIA also is available for SSMO staff members through the submission of observing proposals (for competed time) that are externally peer-reviewed.

Other sets of system users are the Education (Airborne Astronomy Ambassadors) and Public Affairs (media) guests who will fly aboard SOFIA (with Outreach staff escorts) during science operations.

For the purposes of this document, the system operators, the personnel who run the observatory, are distinct from the "users" and are described in Section 2.3.

General Investigators:
General Investigators (GI) will consist of scientists from universities and other science institutions. They will be involved in preparing for a flight series, participating in a current series, or carrying out calibrations or data analysis on a past flight series. A GI will be an investigator who is awarded observing time in response to the SOFIA Call for Proposals.

Instrument Principal Investigators:
An Instrument Principal Investigator (PI) is the single individual who is the leader of the experimenter team and usually a focal-plane instrument owner/developer. An Instrument PI will be an investigator who is awarded funds to develop a science instrument and/or awarded observing time with his or her own science instrument.

Educator and Media Guests:
Members of the U.S. and German educational communities will use SOFIA through the Airborne Astronomy Ambassadors (AAA) Program. This program involves peer-reviewed applications from teachers and other educators to participate in SOFIA science flights. This program, along with onboard Public Affairs activities (e.g., press, VIPs) are conducted in parallel with science operations and are carefully structured so as not to interfere with the science productivity of SOFIA. Observatory science operations are a focal point for educator, media, and public attention. Educator guests will have an unprecedented opportunity to observe and participate in front-line scientific research as it happens. In particular, educators will work as partners with willing scientists and make non-interfering observations of their own as part of a professional development experience.

2.4 Observatory Elements

The SOFIA Observatory System consists of a set of airborne and ground elements that work together to collect, process, and disseminate astronomical data. The major elements of the system are the aircraft platform, which houses the equipment necessary for astronomical observations; the Telescope Assembly (TA), which collects and focuses the IR and visible energy onto the Science Instrument (SI); the Mission Controls and Communication System (MCCS), which controls the Observatory and interfaces with the aircraft, TA, and SI; the Data Cycle System (DCS), which is the science proposal submittal and archival system; and the SIs, which collect the astronomical data.

2.4.1 Aircraft

The SOFIA aircraft is a highly modified Boeing 747, Special Performance (SP) model. The 747SP is 48 feet shorter than a standard 747-100, but with the same engines, wingspan, and fuel tanks, making it lighter and thus extending the range. In addition, the tail of the SP is taller and wider than the -100 models to compensate for handling changes produced by the shortened fuselage. The increased range and stability made the SP an ideal choice for the extended-duration missions required for SOFIA observations.

To incorporate the telescope, a 14.5-foot section of the aircraft pressure shell was removed to create a cavity with an unobstructed view of the sky. The unpressurized cavity is enclosed by a double pressure bulkhead, which maintains a comfortable environment in the crew cabin. A

Cavity Environmental Control System (CECS) conditions the air within the telescope cavity to control temperature and moisture content prior to, during, and after conclusion of flight operations. The fuselage was further modified with doors that move in concert with the telescope to minimize the surface area of the cavity exposed to the aircraft slipstream.

SOFIA includes substantial provisions for new mission support systems, including hydraulic, cooling, cryogenic, vacuum, electrical power, mission control and lighting subsystems.

2.4.2 Telescope Assembly

The TA is a 2.5-meter clear aperture telescope of generic Cassegrain design, with provisions for Nasmyth focal plane mounting of SIs, and includes supporting control, monitoring, and communications equipment.

The TA consists of:

- Optical assembly, including the primary, secondary, and tertiary mirrors and assemblies
- Structural assembly with a metering structure including the TA head ring, to which the Fine Field Imager (FFI) and Wide Field Imager (WFI) cameras used for acquiring and tracking targets are mounted and the Nasmyth Tube Assembly
- Suspension assembly with the hydrostatic bearing, oil supply, coarse and fine drives for TA rotation, Vibration Isolation System (VIS)
- Telescope flange assembly, which includes the Science Instrument Flange, Focal Plane Imager (FPI), the pressure window subassembly, and the TA balancing subassembly
- Pointing and control system with optical cameras, gyroscopes, servo units, controller units for stabilization, tracking and systems monitoring
- Electrical assembly with power distribution units and the harness

2.4.3 Mission Controls and Communications System

The MCCS is the core hardware/software system used for mission monitoring and control on the aircraft, and includes power systems, computer networks, and control software accessed on workstations with associated Graphical User Interfaces (GUIs).

Key functions of the MCCS are:

- Facilitating communication between operators
- Providing users real-time control of the observatory elements such as the telescope, cavity door, and data collection and processing
- Collecting, time-stamping, routing, processing, archiving, and displaying observatory data and images
- Presenting formatted real-time science and operational data to operators, crew, and guests
- Distributing power to observatory systems

2.4.4 Data Cycle System

The purpose of the DCS is to provide a uniform, extensible, and supportable framework for all aspects of the Facility Science Instrument (FSI) program and to provide a common general investigator interface for operating and obtaining data from current and future FSIs. The DCS is composed of the “Core DCS,” the “Archive,” “Observation Planning,” and “Proposal Development.” The DCS also will provide archive and proposal processing support for Principal

Investigator-class Science Instruments (PSIs) and Technology Demonstration Science Instruments (TDSIs).

The DCS tools and infrastructure interoperate in four distinct modes: 1) proposal preparation and submission, 2) observation and mission planning, 3) observation execution, 4) data archiving and distribution. Archived SOFIA science data may be accessed in the DCS by members of the public and SOFIA guest investigators. Only the appropriate guest investigators will have access to data within the proprietary period.

The DCS will be hosted in the SOFIA Science Center (SSC) for access to proposal development, observing plan development, and data archiving operations. A portion of the DCS will be hosted onboard the SOFIA aircraft for access to the observation control process.

2.4.5 Science Instruments

SIs consist of a focal plane assembly mounted to the TA Instrument Mounting Flange, support electronics installed in the aircraft cabin in the counterweight rack and the investigator station in the experimenter racks, and the associated cabling. The SI's are those items designed for astronomical observations aboard the airborne system and are developed by an SI team.

The SOFIA Program has three classes of SIs: Facility Science Instruments (FSIs), Principal Investigator-class Science Instruments (PSIs), or Technology Demonstration Science Instruments (TDSIs):

- FSI: Instruments that are developed for long-term use on SOFIA and are maintained and operated by the SOFIA Observatory after formal delivery to the Program. These instruments are routinely operated and maintained by designated SOFIA Science and Mission Operations (SSMO) FSI scientists, in support of General Investigators. FSIs are general-purpose, reliable instruments for which the process of data acquisition, reduction, and calibration is straightforward and which will routinely support observations by GIs, with assistance from an SSMO scientist.
- PSI: A general-purpose instrument that is at the state of the art throughout its operating life and used for observations by the instrument team (Principal Investigator) and General Investigators, but is operated and maintained by the builder of the instrument and not by SSMO scientists.
- TDSI: Technology demonstration science instruments are developed for the purpose of maturing and demonstrating, through a focused science investigation involving a limited number of SOFIA flights, new capabilities and methodologies of value to SOFIA and future NASA missions. SOFIA technology demonstration science instrument investigations are analogous to NASA's sounding rocket and scientific balloon suborbital investigations. Technology demonstration science instrument investigations are allowed to have higher risk and reduced reliability; in exchange they are expected to have a shorter duration and be significantly less costly than a facility instrument.

SOFIA will develop SIs in stages. Each instrument has its own detailed configurations that are beyond the scope of this document. SOFIA first- and second-generation science instruments are listed below; a brief description of each SI is in Appendix B, Definitions:

- FORCAST
- GREAT
- FIFI-LS

- FLITECAM
- HIPO
- EXES
- HAWC+

2.5 Observatory Architecture and Data Flow

The following is a basic Observatory architecture diagram showing some of the Observatory elements from the previous section and the associated interfaces and data flow, starting from when a Science Investigator submits a proposal into the DCS proposal tool and concluding when the data is received from the DCS Archive. Many support systems, such as the Mirror Coating Facility, as well as some Observatory systems are not depicted.

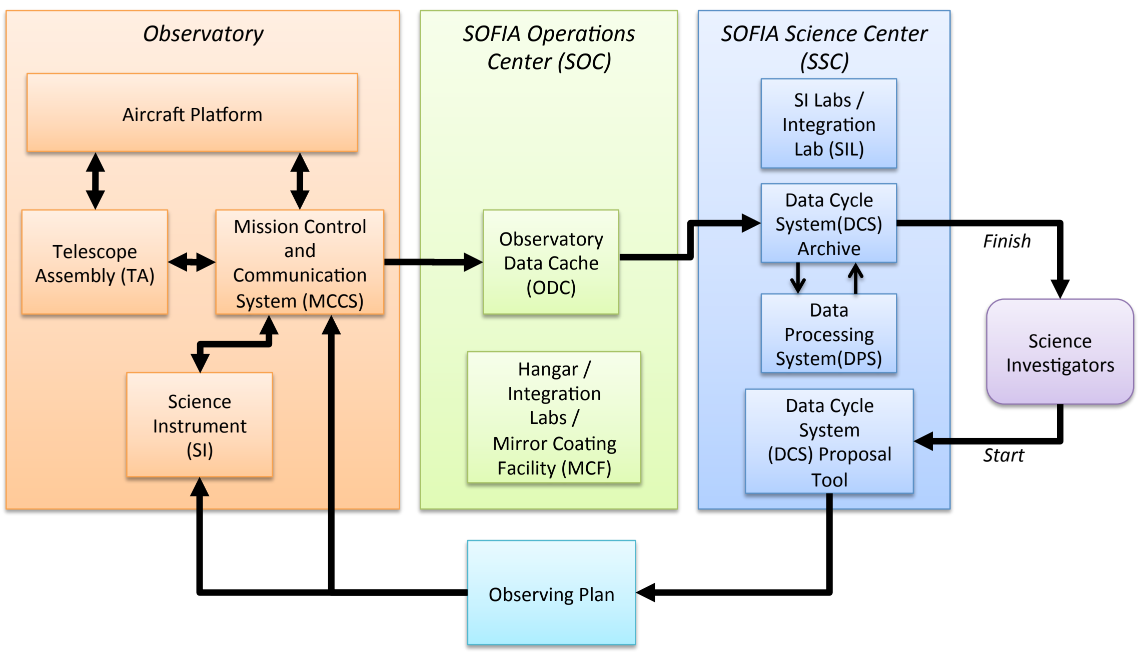

Figure 4: System Interfaces and Data Flow

Raw science data from the SIs will be collected onboard the SOFIA aircraft and (along with additional observatory data) transmitted from SOC ground facilities via high-speed data link to the SSC for processing, archival, and researcher access.

2.6 System States and Modes

The SOFIA system will operate in a number of different modes throughout its lifecycle, including routine science observation modes, special target and deployment modes, maintenance modes, and testing modes.

2.6.1 Routine Science Observer Modes

During routine science operations from DAOF, the system will operate in two observer modes:

- Visitor mode, where the Instrument PI or GI is present on the flight(s), and
- Service/Queue mode where a GI is not present on the flight(s) and observations are carried out by SSMO staff.

To improve observing efficiency, requested FSI observations (on behalf of GIs) are entered into an observing queue and carried out when conditions and scheduling permit. Generally, all Instrument PI observations are done in visitor mode, and GI's visitor mode observations are grouped together with these PI observations during scheduling; however, most GI observations will likely occur in service mode.

2.6.2 Special Targets and Deployment Modes

As an Airborne Observatory with extended range, one of the primary capabilities of SOFIA is to travel throughout the globe to make astronomical observations in different portions of the sky or in response to unique astronomical events. Typically SOFIA will deploy to the Southern Hemisphere once per year for two weeks to observe targets that have insufficient visibility from the Northern Hemisphere. Targets of Opportunity (ToO), such as supernova or eclipses, may require SOFIA to take off or land from a location other than DAOF and therefore would constitute a deployment of the Observatory.

2.6.3 Maintenance Modes

Maintenance is required for all of the Observatory elements described earlier, with aircraft maintenance and mirror recoating being key drivers of SOFIA's overall schedule. Minor aircraft maintenance will occur on a routine basis during science operations with pre-flight, through-flight, and post-flight checkouts. The TA requires maintenance for mechanical, electrical, hydraulic and optical subsystems as defined in the TA maintenance plan. TA maintenance will occur between flights and during scheduled observatory maintenance periods. These three 4-week maintenance periods occur throughout the year to perform standard periodic maintenance of the aircraft platform and TA mechanical systems.

Another major maintenance activity is Primary Mirror cleaning and recoating. To maintain telescope performance the Primary Mirror must be recoated periodically based upon reflectivity measurements across the wavelength range. Mirror recoating requires the mirror to be removed from the aircraft in a "critical lift" operation, transferred to the Mirror Coating Facility (MCF), recoated, and returned to the aircraft. The complete process takes up to 45 working days.

MCCS, DCS, DPS, and SIs will be maintained on an ongoing basis throughout the lifespan of SOFIA, with MCCS undergoing periodic upgrades as part of its continuous improvement program (described in Section 5.6.2 Mission Systems Maintenance).

2.6.4 Test and Evaluation Modes

SOFIA will be operated in a number of testing modes and environments to check out new capabilities, integrate new SIs, prepare for science flights, and characterize Observatory performance, among other purposes. Testing modes include:

- Systems Integration Laboratories (SILs)/Hardware-in-the-Loop Simulators (HILS)
- Telescope Assembly Simulator (TASim)
- Hangar Operations – Testing functionality of TA, MCCS, and/or SI

- Line Operations – Nighttime testing with the SOFIA aircraft on the flight line and the door open in order to checkout Observatory performance on the sky
- Performance Characterization Flights – Flights conducted specifically to gather data to determine performance of the Observatory
- SI Commissioning – All ground and flight tests required to verify SI functionality and integration with the Observatory and must be completed prior to the SI becoming available to General Investigators for observations
- V&V Testing – Verification and validation tests that are conducted as part of overall Observatory acceptance or as new capabilities are introduced

2.6.4.1 Systems Integration Laboratories

The Observatory has four Systems Integration Laboratories (SILs).

Three SSC SILs:

One is the primary development platform for observatory-related software and uses the same flight hardware and operating system releases as the flight system. The second and third SILs are used for development, training, and testing purposes (e.g., checking TA command interfaces, confirming data acquisition, and evaluating new concepts). SIL software installations are adaptable to three software configurations: 1) baseline aircraft, 2) version under test, and 3) evaluation (e.g., uncontrolled).

One SOC SIL:

This SIL is used for development, training, and testing purposes (e.g., checking TA command interfaces, confirming data acquisition, and evaluating new concepts).

2.6.4.2 Hardware-in-the-Loop Simulators

The Observatory has two Hardware-in-the-Loop Simulators (HILS).

1) The Development HILS Lab allows development and informal testing of the MCCS without the dedicated use of the Observatory. It also supports 747-SP platform simulation development and a TA hardware/software development environment. The Lab uses flight-equivalent hardware (non-ruggedized) for the Platform Interface Subsystem (PIS), TA Image Processing Subsystem (TAIPS), Data Acquisition Subsystem (DAS), Archiver, time server, and Workstation Subsystem (WS).
2) The Verification and Validation (V&V) HILS Lab is used for formal MCCS V&V activities. This provides the ability to conduct mission rehearsals and to perform Telescope Operator and Mission Director training. The Lab makes use of flight spare hardware for the PIS, TAIPS, DAS, Archiver, time server, WS, and network.

2.6.4.3 Telescope Assembly Simulator

Telescope Assembly Simulator (TASim) is designed to simulate the Telescope Assembly dynamics and software interfaces to the MCCS. Developed at the Science Center, it is used in the SIL and HILS environments for development, verification and validation activities for the MCCS PIS, TAIPS, and Workstation GUI, for MCCS integration with SIs and for mission planning purposes.

2.7 Requirements and Metrics

2.7.1 Top-Level Requirements

The following top-level or level-1 requirements are presented in the SOFIA Program Plan (SOF-DF-PLA-PM01-1000). The milestone Full Operational Capability (FOC) marks the start of science research and is defined as being satisfied when four Science Instruments have been commissioned and are available to the science community.

1. The effective aperture of telescope shall be 2.5 meters
2. The Telescope elevation range (un-vignetted) shall be 23 – 58 degrees
3. The Telescope wavelength range shall be 0.3 to 1600 microns
4. The Observatory shall be diffraction-limited at 20 microns. This requirement shall be achieved by FOC + 4 years.
5. The Observatory shall be capable of making science observations for at least 4 hours at altitudes of at least 35,000 feet at ISF; and at least 6 research hours at altitudes of at least 41,000 feet at FOC.
6. The Observatory shall be capable of global operations
7. The Observatory shall be capable of changing instruments between each flight
8. The Observatory shall be capable of 20 years of operations
9. At FOC + 4, the Observatory shall be capable of supporting at least 40 distinct observing programs and their associated science teams per year.
10. At FOC + 4 years, the Observatory shall provide 960 research hours per year.
11. For Basic Science, the number of science instruments available for in-flight research shall be at least 2 (1 NASA, and 1 DLR).
12. At FOC, the Observatory shall demonstrate full science operational capability with 4 available instruments.
13. The program shall implement education and public engagement activities.

2.7.2 Key Performance Metrics

The SOFIA Program will track and report metrics to monitor system performance and ensure that certain requirements, especially the Level-1 requirements in the previous section, are being met. Some of the key metrics are listed below:

Research Hours (RH)
The time all observatory systems are working sufficiently to obtain astronomical data at the desired observing altitude.

Science Flight Hours (SFH)
The time the TA is tracking a target at the desired observing altitude.

Data Collection Time (DCT)
The time an SI is taking data of a tracked target at the desired observing altitude.

Encircled Energy Image Size
A measure of telescope image quality that is fundamental to Observatory performance.

3 OPERATIONAL OVERVIEW

This section provides an overview of Observatory operations, describes key operational constraints, describes the operational and planning facilities, key personnel roles and responsibilities, and the Program organizational structure.

3.1 Mission Overview

SOFIA's overall mission is to conduct science data collection flights on behalf of science investigators who propose astronomical observations suited to SOFIA's capabilities. These science flights are conducted as part of a Science Observing Cycle, which is typically one year in length. As such, SOFIA's mission is organized around a cycle-by-cycle framework whereby science observations are proposed and selected, new SIs or Observatory upgrades are potentially added to SOFIA's capability, Outreach (educator and media) guests are selected, maintenance periods are defined, and other advanced planning is completed. This advanced planning is pulled together into an Annual Operating Plan and forms the basis for the Cycle's activities. This is depicted in the top half of Figure 5, Overall Depiction of SOFIA Activities.

The remainder in Figure 5 flowing from the Annual Operating Plan shows the operations that are part of a Science Observing Cycle, including the supporting activities such as maintenance and the handling of the science data once the Observatory completes a flight. A Science Observing Cycle itself is comprised of a number of Flight Series, the term for the contiguous science flights that all use the same SI and that typically last two weeks. The bottom right part of the figure conveys the transfer and archival of science data, as well as the "pipeline" processing that takes the raw science data and creates derived science products for investigators.

Section 5 describes the planning and operations in further detail, while Section 4 provides the SOFIA Organizational structure and a high-level overview of the management structure.

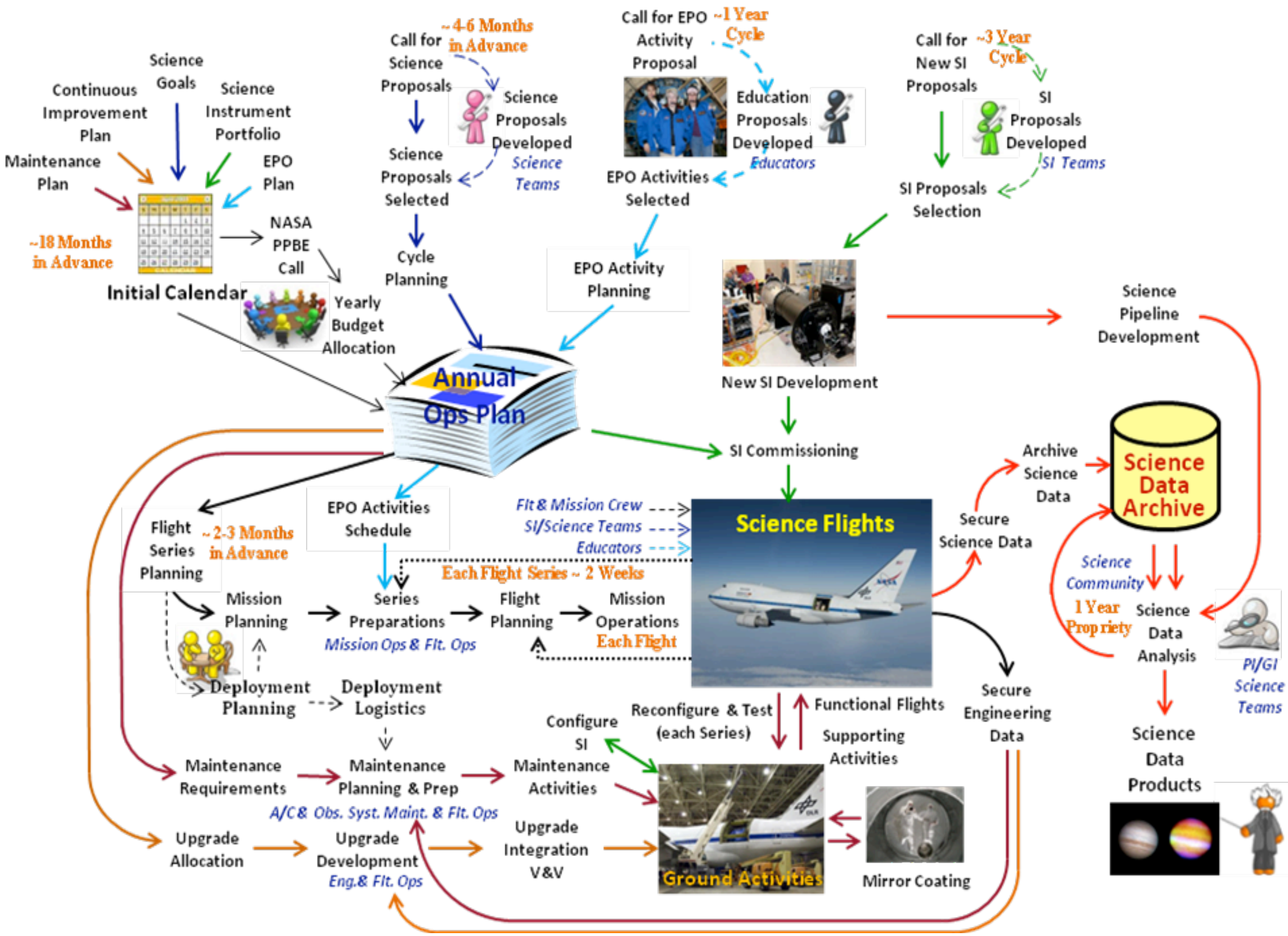

Figure 5: Overall Depiction of SOFIA Activities

3.2 Operational Policies

The Observatory has a number of operational policies covering both Science and Mission Operations and Aircraft Operations. These include policies related to work schedules; flight, ground, and maintenance crew; flight rates; science proposals; observations; deployments; and other areas. Historically, these policies have been described in the ConOps; however, as SOFIA moves towards operations, these policies will be maintained and updated independently of this document. This document describes the policies as they are understood at the time of document release, but are not authoritative. The SSMO maintains a SOFIA Observatory Policies document, (SOF-AR-PLA-PM01-2005) which is located on Windchill.

3.3 Operational Constraints

SOFIA operations are constrained by a number of factors. Observation proposals may contain targets that are only viewable during certain times of year, which will constrain when those observations can be made. Dedicated aircraft maintenance periods, determined as part of the Annual Operating Plan, occur three times a year in four-week increments, during which time no science observations can occur. SOFIA Science and Mission Operations (SSMO) and Aircraft Operations (AOPS) policies also constrain operations. Those specific to operations include crew fatigue limits, weekend work and holiday policies, among others. There are weather constraints, including dew point and wind speed limits for line operations.

3.4 Ground Support Facilities

The Observatory Ground Support Facilities (GSFs) are located at two NASA Centers:

- SOFIA Science Center (SSC) at Ames Research Center (ARC)
- SOFIA Operations Center (SOC) at the Armstrong Flight Research Center (AFRC)

3.4.1 SOFIA Operations Center (SOC)

The SOFIA Operations Center (SOC) is a Ground Support Facility at the NASA Armstrong Flight Research Center (AFRC) in the Armstrong Aircraft Operations Facility (DAOF) Hangar 703 in Palmdale, California.

Personnel with a home base at the SOC include NASA's prime contractors for the execution and implementation of SOFIA aircraft and flight operations, the NASA program management and related support contractors. The SOC also is home to science mission operations support personnel.

Aircraft and flight operations are based at the SOC, where the SOFIA aircraft resides. The aircraft, telescope assembly (TA), and commissioned Facility-class Science Instruments (FSIs) are maintained at the SOC. Science mission operations are supported at the SOC, including science instrument integration into the Observatory.

Key ground support facilities at the SOC include:

- Science instrument readiness rooms (IRRs)
- Pre-flight Integration Facility (PIF), including TAAS
- Systems Integration Laboratories (SILs)
- Hardware-in-the-Loop Simulators (HILS)

- Mirror Coating Facility (MCF)

3.4.2 SOFIA Science Center (SSC)

The SOFIA Science Center (SSC) is a Ground Support Facility at the NASA Ames Research Center (ARC) in the Sustainability Base (Building 232) and Building 211 at Moffett Field in Mountain View, California.

Personnel with a home base at the SSC include NASA's prime contractor for the execution and implementation of SOFIA Science Mission Operations (SSMO), the NASA program management and related support contractors.

At the SSC, the prime SSMO contractor performs work related to the preparation, solicitation, evaluation, and selection of observation proposals; planning and sequencing of observations; science flight planning; science mission operations; the processing, archiving, and distribution of science data; and public engagement and science community outreach.

Key ground support facilities at the SSC include:
- SSMO server
- DSI computer laboratory
- DSI optics laboratory
- DSI thermal vacuum test laboratory
- EXES science instrument laboratory
- Systems Integration Laboratories (SILs)

4 OPERATIONS MANAGEMENT

Descriptions of the major management and operations groups and a listing of some key personnel will be provided in the Level-2 ConOps, which is in development. The Level-2 ConOps document will describe most activities as being conducted by one of these operations groups (e.g., Mission Ops, Science Ops, Aircraft Ops, Ground Ops, and Maintenance) and will identify the roles and responsibilities for key operations functions. Further details of the roles and responsibilities of specific personnel will be presented in the Level-2 ConOps document.

4.1 Organizational Structure

The operations management structure that will be in effect at the completion of Observatory development is comprised of a SOFIA Program Office that oversees Science and Mission Operations and Airborne Operations. The details of the organizational structure are described in the SOFIA Program Plan (SOF-DF-PLA-PM01-1000).

The Program operational organization (post-development) is presented in Figure 6 on the following page. SOFIA team members are either assigned to the Program Office (led by the Program Manager) or to one of the following three organizational structures: Operations (led by the Operations Director), the SSMO (led by the SSMO Director), or Observatory Systems (led by the Observatory Systems Director). Roles and responsibilities are detailed in the SOFIA Program Plan.

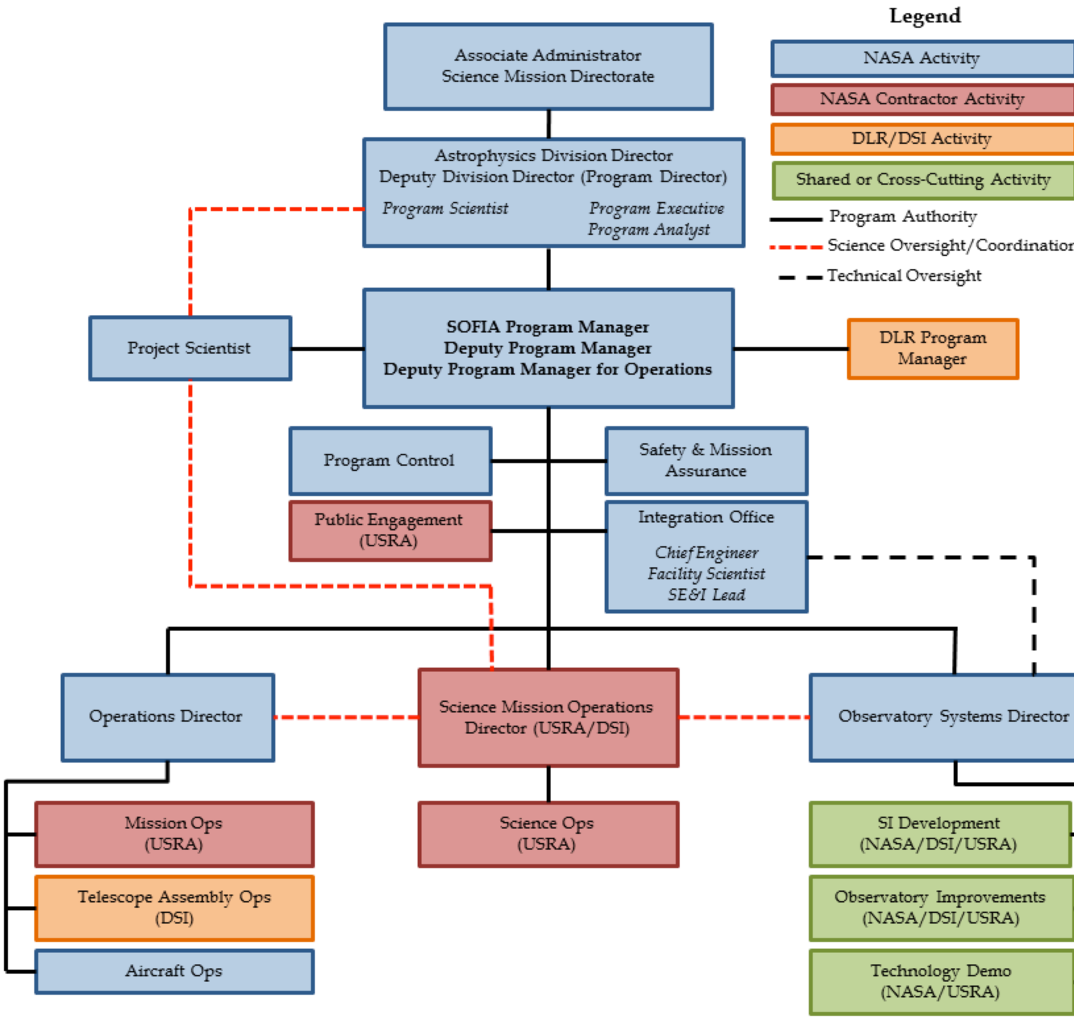

Figure 6: Operations Organization for SOFIA

4.2 SOFIA Program Office

4.2.1 Responsibility and Authority

The Science Mission Directorate (SMD) at NASA Headquarters, the sponsor of the SOFIA program, has delegated implementation responsibilities to the Program Manager, who resides at the Armstrong Flight Research Center (AFRC) during the development phase. The Program office transitions to the Ames Research Center (ARC) at the completion of development, or Full Operational Capability (FOC), as agreed to by both centers and HQ Astrophysics division.

4.2.2 NASA/DLR/Contractor Functions

NASA's and DLR's roles and responsibilities are agreed upon in the Memorandum of Understanding for the SOFIA Program, signed by NASA and DLR in 1996 and amended for another ten years in 2006. NASA and DLR are responsible for the overall management of the Program and supporting contractors.

NASA's primary program contributions are to develop and provide the modified aircraft, MCCS, and Science and Mission Operations functions; to provide integration, testing, verification and operation of the complete SOFIA System; and to prepare and implement plans for the U.S. share of the scientific utilization of research flight hours on a long-term, continuing basis.

It is NASA's responsibility to manage and operate the SOFIA System and to accomplish programmatically set science goals with close collaboration between DLR, NASA's Project Scientist, NASA's Facility Scientist, NASA's Operations Director and the Science and Mission Operations (SSMO) Director.

The primary contributions of the DLR are to develop and provide the Telescope Assembly (TA); support its integration, testing, verification and operation, including maintenance as an integral part of the SOFIA system; and to prepare and implement plans to provide the German share of the scientific utilization of research flight hours on a long-term, continuing basis. The TA system is managed under the authority of NASA's Operations Director.

It is DLR's responsibility to maintain the TA and participate in the operations phase of the SOFIA Observatory on a long-term, continuing basis in cooperation with NASA by provision of services, equipment and consumable supplies and materials to the Observatory through the selected German prime contractor for operations.

The U.S. science program will be managed through NASA's prime contractor for SOFIA Science and Mission Operations (aka the SSMO organization). The German science program will be managed in Germany and integrated with the US science program through the SSMO organization.

The NASA/DLR Joint SOFIA Program Plan (JSPP) Part II (SOF-DF-PLA-SOF-1005.2) provides additional information on how NASA and DLR will jointly operate the SOFIA Observatory.

4.3 Education and Public Engagement

The SOFIA Program is responsible for conducting Education and Public Engagement programs that exploit the unique and inspirational attributes of airborne astronomy to contribute to common U.S. and German goals for the encouragement of science, technology, engineering, and mathematics (STEM) education, and to the general elevation of public scientific and technical literacy.

SOFIA is the only major research observatory designed from the start to bring non-scientists into close contact with scientists in a research environment. SOFIA is thereby especially capable of giving science educators direct exposure to the scientific process.

SOFIA's capability to give educators access to frontier astronomical research has driven the design of the mission's Education and Public Engagement programs, the particular goals of which are to:

1. Enhance STEM education in select U.S. and German communities by inspiring, engaging and educating educators and students.
2. Establish long-term relationships between educators and students in those communities, and SOFIA scientists and engineers.
3. Contribute to general public understanding of the value of scientific research.

These goals will be achieved especially by having educators partnered with SOFIA researchers and engineers and by having educators participate in the Observatory's research flights. Specific Education activities include the flagship Airborne Astronomy Ambassadors (AAA) educator professional development program—providing training, research flight experience, and U.S. and German educators followed by support from SOFIA Outreach for their respective efforts to improve STEM education and public science literacy in their home communities as ambassadors for NASA, DLR, and SOFIA. In addition, other professional development opportunities will be conducted for educators, e.g., the Earth Partners (EP) program in which the Outreach group supports educators for professional development and local SOFIA- and NASA (or DLR)-oriented education and public engagement efforts with mentoring by SOFIA scientists and engineers but without a flight experience. In both the AAA and EP programs, the Outreach team will produce and disseminate standards-based curriculum materials related to SOFIA's mission, IR astronomy, and the electromagnetic spectrum as well as presenting SOFIA exhibits and materials at education and science professional meetings.

4.4 Science and Mission Operations (SSMO) Responsibility

SSMO contractor is responsible for implementing all science-related activities for the program, including support to the science community for the preparation of observation proposals; solicitation of observation proposals; evaluation and selection of observation proposals; planning and sequencing of observations; support of observatory operations (such as support to telescope and Science Instrument operations); and processing, archiving and distribution of science data.

Under the direction of NASA management, the SSMO supports SI development and commissioning activities. The SSMO will operate and maintain Facility-class science instruments (FSIs) upon formal acceptance and hand-over from the SI team to the SSMO

DLR and their prime contractor are responsible for developing, implementing, testing, operating and maintaining the TA system. The DLR prime contractor will implement any significant enhancements or improvements to the TA after approval by the Program Office. As the primary users of the TA, it is envisioned that SSMO will play an active role in identifying and proposing enhancements and upgrades to the TA and aircraft systems.

4.5 Aircraft Operations Responsibility

SOFIA Aircraft Operations (AOPS) is responsible for the safe and successful science operation and implementation of the SOFIA aircraft, including mission systems and is accountable for proper execution of all aspects of these operations and reports directly to the SOFIA Operations Director. The SOFIA Operations Director establishes an interface directly with AOPS through development and approval of the Airborne Systems Operations Plan. Airborne Systems Operations works directly with the SOFIA Operations Director in accomplishing operations, particularly in the area of resource allocation and utilization, oversight, reporting and resolution of AOPS issues. AOPS will notify the SOFIA Operations Director if successful achievement of the minimum project objectives is not possible within the prescribed constraints.

4.6 Program Element Interfaces

An important aspect of the SOFIA Program and supporting elements is the managing of internal interfaces. Within the Program, the roles and responsibilities of SSMO and Airborne Operations (Aircraft and Flight Operations) require close coordination and cooperation. All coordinated operational activities that require a formal hand-off or deliverable from one element to another will be discussed and decided during weekly Integrated Operations team meetings. To facilitate collaboration, the SOFIA Program Systems Engineering and Integration Office uses working groups and boards. These include the following:

- Program Management Board (PMB) – Is the governing authority for the SOFIA Program. The PMB is responsible for the change management of Program requirements, schedules, resources, configurations, and end-item specifications.
- SOFIA Engineering Review Board (ERB) – Responsible for cross element technical reviews involving multiple stakeholders
- SOFIA Integration IPT – Responsible for coordinating integration activities across the Program
- Program Risk Management Board – Responsible for managing cost, schedule, and technical risk across all Program elements

5 OPERATIONAL PHASES

This section describes the operations phases for the SOFIA Observatory's users, operators, and maintainers. It is organized by the following major activities:

- Observatory Operations and Planning
- Observatory Certification and Commissioning
- Flight Series Preparation
- Science Mission Operations
- Post-Flight Operations

- Planned Maintenance
- End-of-Program Disposal

In addition to typical operations, this section covers commissioning activities, planned deployments and rapid-response deployments to respond to unplanned astronomical events or Targets of Opportunity (ToO).

5.1 Observatory Planning

The key to successful operation of the Observatory is the optimized planning of various operational and developmental activities. This includes Observatory Operations Planning (5.1.1), Observatory Improvements and Enhancements (5.1.2), Science Observing Call for Proposals and Selection (5.1.3), Science Instrument Announcement of Opportunity and Selection (5.1.4), and Observing Cycle Planning and Scheduling (5.1.5).

As a complex program with an intended operating lifetime of 20 years, there is a need for overall planning to look many years into the future. Plans are created for each observing cycle, flight series, and individual flight. This section addresses the planning stages leading to observing cycle planning, which typically covers a period of one year. More detailed planning is described in Sections 5.3 Flight Series Preparation and 5.4 Science Mission Operations.

5.1.1 Observatory Operations Planning

Observatory operations planning begin with long-term planning activities that identify, analyze, prioritize and phase various objectives and requirements. Science goals or objectives are the biggest drivers, followed by required aircraft and Observatory system maintenance activities and desired enhancements. SOFIA long-term planning includes strategic planning for long-lead development items including new SI capabilities and Observatory system upgrades that can take several years to achieve.

Operations planning include the development of a baseline schedule (5.1.1.1) and the SSMO Annual Operating Plan (5.1.1.2).

5.1.1.1 Baseline Schedule

The baseline schedule (see example Figure 7) provides dates and durations for all major SOFIA activities, including science observing windows, maintenance downtimes, SI commissioning, deployments, science observing cycle calls, new SI calls, mirror coating, and major observatory upgrades. With this baseline, the Program can evaluate schedule impacts of proposed or requested changes and provide a means to plan the yearly cycle of science operations. The Program baseline schedule is one of the primary inputs to the SSMO Annual Operating Plan and includes the following:

- Available science observing windows
- Aircraft and mission systems maintenance requirements
- U.S. and German holiday calendar
- Science instrument commissioning
- Continuous improvement downtime

The baseline schedule will be updated and maintained throughout its useful life.

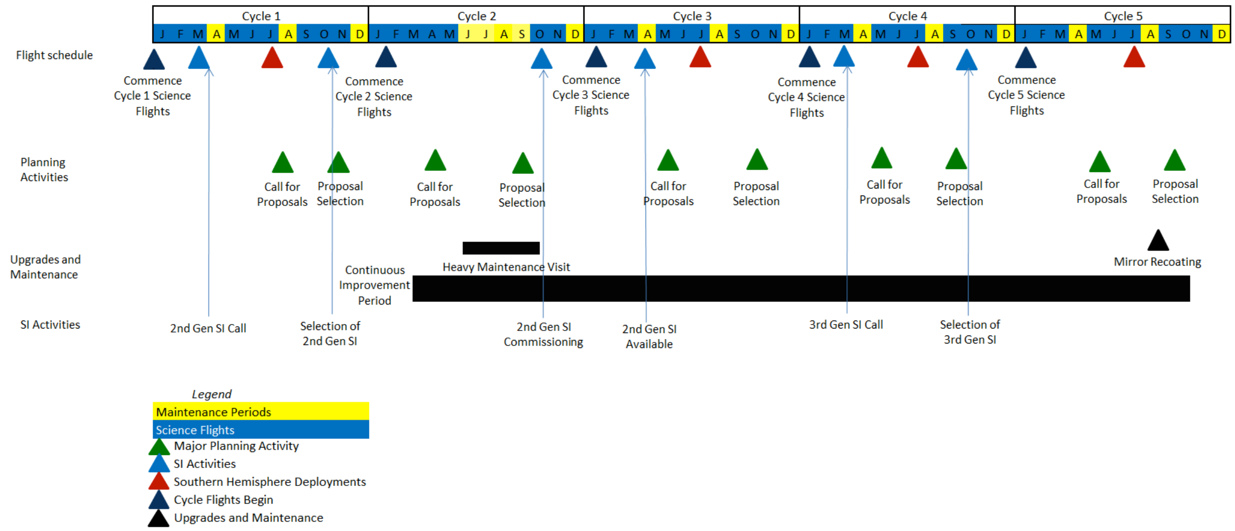

Figure 7: Example Baseline Schedule with Major Milestones

5.1.1.2 SSMO Annual Operating Plan

The SSMO Annual Operating Plan contains a summary of observations and activities for the coming twelve-month period. It is developed as an annual schedule addressing SOFIA Science Center (SSC) and SOFIA Operations Center (SOC) activities for the included period, including scheduled aircraft maintenance and incorporation of new capabilities.

Updated lessons learned and risk assessment for the coming year are included, as well as observatory performance metrics with associated reporting plans for each. The Annual Operating Plan accounts for phasing and integration of all major activities. Figure 8 shows how the planning process must account for many parallel flight and planning activities that occur throughout a year.

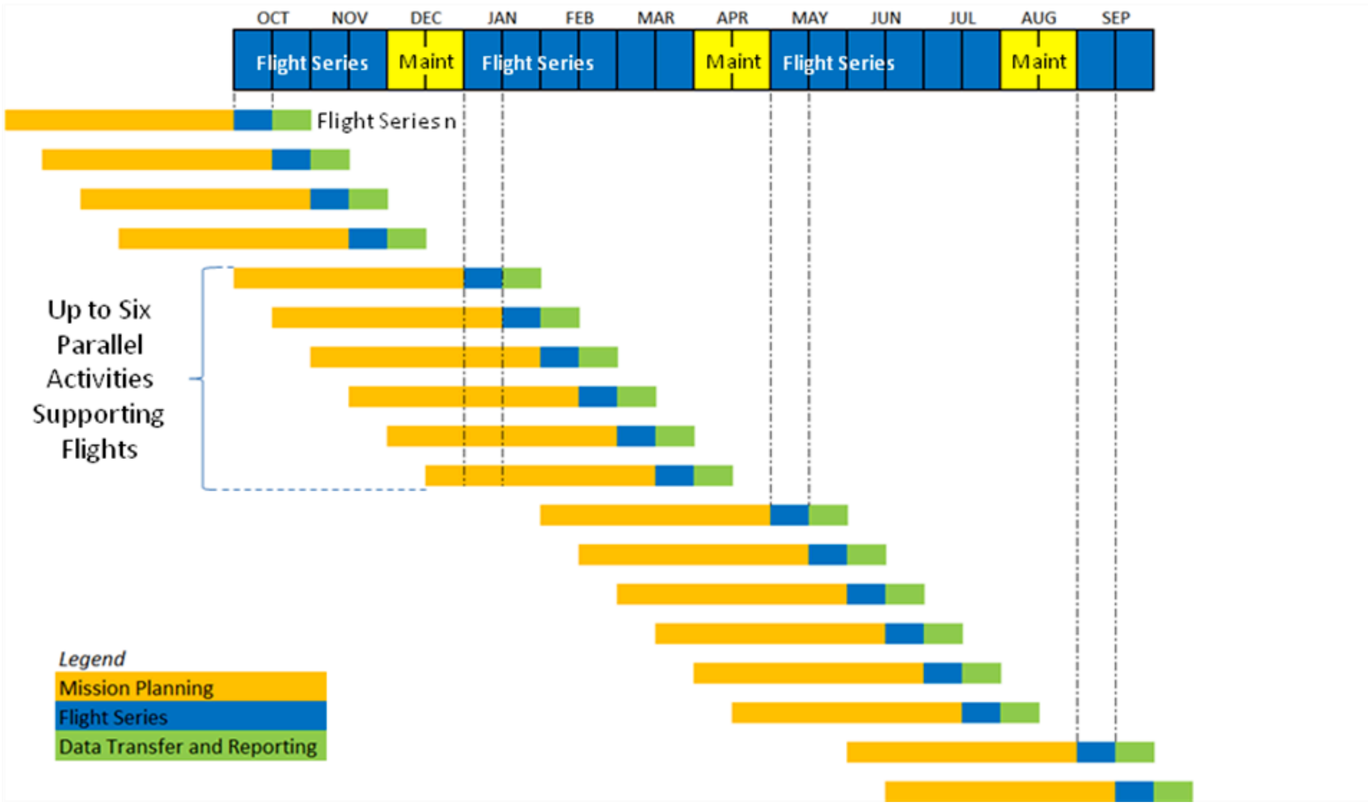

Figure 8: Annual Operating Timeline

The Annual Operating Plan is developed with consensus and contributions from all stakeholders, each of whom are integrated into the plan development process. The plan is developed by the Program Office in concert with the Observatory Operations Director, the SSMO Director, and the Airborne Systems Operations Director. This plan is approved by the Program Management Board (PMB) and maintained through the SOFIA Program Configuration Management process.

Each year, the Annual Operating Plan is reviewed and approved by the SOFIA Program Office. The Armstrong Flight Operations Directorate and the Armstrong Office of Safety & Mission Assurance will review the document.

5.1.1.2.1 Annual Planning Guidance and Assumptions

There are important assumptions that must be provided to conduct consistent and effective operations planning. Many of the assumptions in the process come from programmatic guidance and high-level requirements while others come from estimates in performance or Reliability and Maintainability (RAM) analyses. The following summarizes the key assumptions that feed into the long-term planning process:

1. The requirement to achieve 960 Research Hours starting at FOC +4 years. (Program Commitment Agreement)
2. There will be 36 to 38 weeks available for science flights each year with the following constraints:

There are three equally spaced, four-week maintenance down-time periods (12 weeks total) required each year. The window for the 4-week periods can be shifted to occur two weeks earlier or later in the schedule before having an adverse impact on the program schedule. Nominally the maintenance down times will be scheduled in mid- December, April and August.

3. SI commissioning will nominally occur over two to four weeks every 24 to 36 months as new SIs come online.
4. Flight series will be nominally scheduled to allow SIs to be changed out over weekends.
5. Four flights will be nominally scheduled each flight week.
6. No flights will be planned on weekends or holidays, except to meet high-priority requests for targets of opportunity.
7. The Observatory System Effectiveness, SE_O (including SIs) is assumed to be 82% based on incomplete RAM analysis.
8. Results in 1171 hours of RH that must be planned for each year to reach the actual 960 required (1171=960/0.82). Planning 36-38 flight weeks per year provides 1,152 – 1,216 planned RH.
9. The Dispatch Reliability (R_D) rate for the year is assumed to be 90% (goal stated in SE01-003). That is, it is assumed one out of ten planned flights will not occur and must be accounted for in the planning.
10. Science flights will be planned to last nominally10 hours, with nominally 9 hours of RH available for each flight.
11. The actual RH that will be achieved is assumed to be 91% of the RH planned for each flight based on the assumed Observatory System Effectiveness and Dispatch Reliability. This indicates that after accounting for dispatch reliability, the observatory must be 91% effective after launching (.91 = .82/.90). Thus an average of 8.2 hours of actual RH will be achieved for each flight where 9 hours of RH are nominally planned.
12. Planned deployments will be scheduled once per year for nominally two weeks of observations.

5.1.1.3 Fundamental Observatory Operations Planning Terms

Science Flight Grouping Definitions:

These grouping definitions only apply to science flights, defined as flights with the primary purpose of collecting publishable astronomical research data.

Science Flight: One flight, takeoff to landing, primarily devoted to obtaining publishable astronomical science data. There may be observations taken in response to more than one proposal within one science flight. It is even conceivable that there may be more than one science investigation PI onboard during one science flight.

Science Flight Series: A contiguous series of individual Science Flights, all with the same SI. In other words, a Science Flight Series ends either with an instrument change or the end of the

Science Flight Campaign. There will likely be observations addressing different accepted proposals during a Science Flight Series, and there will often be different GI teams flying during a Science Flight Series.

Science Flight Campaign: One or more Science Flight Series, beginning and ending with a non-science activity. Examples of a non-science activity are a series of engineering flights that are not devoted to collecting science data; an extended period where the aircraft is grounded for maintenance; an extended period where the aircraft is grounded for telescope or mission systems upgrades; extended periods where the aircraft is grounded because of a long holiday period. Ferry flights for deployments are a special case. In general deployment ferry flights will be part of a Science Flight Campaign and will not cause the ending of one campaign and the start of another.

Science Observing Cycle: One or more of Science Flight Campaigns that are covered by a single science Call for Proposals. These calls are issued roughly annually during the normal science mission operations period, so a science observing cycle will be roughly a year in length, except for those years where extended aircraft maintenance is required (D-checks).

5.1.2 Observatory Improvements and Enhancements

The goal of Observatory improvement and enhancement activities will be to enable SOFIA to achieve its full potential and to meet its Level-1 performance requirements. Between FOC and FOC + 4 years the priority will be to implement the improvements and enhancements needed to achieve the Ready for Sustained Science Operations (RSSO) requirements and the FOC + 4 performance requirements. Additional Observatory improvements will be ongoing throughout the expected 20-year operational lifespan of SOFIA. Desired Observatory upgrades, improvements and bug-fixes will be prioritized on a yearly basis by the Integration Office. The Observatory Systems Director is responsible for determining the plan to address the desires given the priority and available budget. Implementation of any changes must be accomplished on a non-interference basis with planned science flight series and maintenance periods unless otherwise approved by the Program Management Board.

5.1.3 New Science Observing Call for Proposals and Selection

SOFIA Science will follow a yearly observing cycle, nominally following the calendar year. The annual call for science proposals is conducted by the SOFIA Science Center. Announcements to the astronomical community will be made through SOFIA web pages, email lists, and American Astronomical Society (AAS), Astronomische Gesellschaft (AG), and European Astronomical Society (EAS) newsletters.

Proposal calls are expected to elicit about 200 or more proposals competing for the targeted 960 Research Hours (RH) target for a year, 80% of those observations from the U.S. side. Science Mission Operations Director and supporting team are responsible only for the U.S. call for proposals. For German observing time, 20% of the RH goal (or ~200 RH) will be solicited and selected independently through DLR processes. On the rare occasion where U.S.-German selection conflicts arise, the SSMO Director and the SSMO Deputy Director (German representative) will provide resolution. Approximately 40 distinct observing programs and their associated science teams will be supported in a yearly cycle.

The U.S. observing Call for Proposals will be open to all qualified astronomers, including instrument teams and SOFIA staff scientists, and will identify what SIs and capabilities are available to GIs. The time requested by a team led by a U.S. observer to use a German SI will be charged to U.S. observing time, and will be judged by the U.S. peer review. The time requested by a team led by a German GI to use a U.S. SI will be charged to German observing time and will be judged by the German peer review.

A two-phase proposal and observation planning process, similar to other NASA projects (HST, FUSE, etc.) will be implemented. This process will focus proposers' first efforts (the proposal) on science justification and their second efforts (observation planning) on observation construction and execution. This two-phase approach is also used to accommodate planning differences between FSIs and PSIs.

Using the DCS capabilities, Science Operations carries out the science call and selection activities, which include the following: releasing a call-for-proposals to solicit submissions; preparing the DCS, "opening" it for proposal submission, "closing" it at the end of the submission time window, and setting relevant access permissions; and performing peer/technical reviews, selecting the best proposals, and managing reviewer access.

Proposals are subject to a peer review organized by SSMO and conducted by the Time Allocation Committee (TAC). SSC science staff provides technical reviews (feasibility evaluations), with additional feasibility inputs from PI teams where GIs have proposed using PSIs for observing. After the initial technical reviews, the TAC convenes to review and rank the proposals. The SSMO Director in collaboration with the NASA Project Scientist will formulate instructions to the TAC. The SSMO Director is the selecting official for the proposals based on the TAC recommendations.

Aside from the observations allocated through the annual call for proposal, there are other types of observations allocated through other processes. Guaranteed Time Observations (GTO) are allocated to instrument development teams as reward for developing the instruments. The allocations of Guaranteed Time are detailed in the SOFIA Science Utilization Policies. During SOFIA Operations, seven percent of the U.S. observing time may be designated as Director's Discretionary Time (DDT), which will not be peer-reviewed by the annual committee, but will be allocated at the discretion of the SSMO Director. DDT may include observations such as Targets of Opportunity (ToO), staff observing time, and special projects. ToO requests are reviewed by *ad hoc* committees at the discretion of the SSMO Director. The SSMO Director, as the selecting official, may not compete for observing time.

Approved proposals are used to generate all of the planning and execution products necessary to conduct science flights.

5.1.4 Observing Cycle Planning and Scheduling

Based on the cycle targets and associated proposals approved through the science call and selection, the goal of cycle planning and scheduling is to determine the overall feasibility of conducting the approved observations. This planning and scheduling activity is performed once per cycle at least three months in advance of the first flight series. Periodic adjustments to the plan are then conducted throughout the cycle as events warrant and the flight series nears.

SciOps, SMO Director and NASA program management provide the major inputs for cycle planning and scheduling. Approved proposals are called Observation Plans and undergo a process of refinement (the second phase of the proposal process) between SciOps staff and the General Investigator who submitted the observation proposal before being delivered to MOPS for cycle scheduling. The SSMO creates an Annual Operating Plan that defines the time periods in the cycle that are being reserved for aircraft downtime, maintenance, upgrades, deployments, and any other special activities. The operational groups will base their own plans and schedules on this Annual Operating Plan.

Using the Observation Plans and the Annual Operating Plan as inputs, MOPS generates the Flight Series Schedule using the Cycle Scheduler (CS) tool. The approved Observation Plan targets and calibrators are retrieved from the DCS and input into CS to determine their visibility windows over the cycle. For each applicable SI, the CS compares the relevant target visibility windows to determine an appropriate Flight Series Schedule (also known as an instrument schedule), which combines the schedules for each SI to cover the cycle.

Instrument installations are planned to span a two-week period nominally, so that all Observation Plans are prioritized and built into a Flight Series based on the their relative rating as assigned by the Time Allocation Committee (TAC). Approved DDT observations and known ToO are built into the Flight Series at this time.

Flexibility has been designed into the Flight Series to provide some minimum slack in their development by:

- The number of flights necessary to achieve the desired RH will be over-allocated. Seven of eight scheduled flights will result in a return of data sufficient to meet the requirement.
- Of the fourteen days (two weeks) in a planned Flight Series, flights are scheduled on only eight of those days.
- Observation time is awarded as hours per requested instrument, not specific flights. This observation planning strategy provides the flexibility to remove lower priority observations from a series schedule, to be observed at some later time.
- Long-range flight and mission planning allow for adaptation of existing plans rather than necessitating the origination of plans on short notice.

In the next step, the Cycle Scheduler “bins” targets into each series in the Flight Series Schedule, so that as many targets as possible are allocated over the cycle. The tool assesses the overall viability of the various combinations of targets during series and flights; any problematic targets are reallocated, as possible, to fit them into the overall cycle plan. The resulting schedule of targets within the various Flight Series is called the Observing Schedule.

The primary outputs of cycle planning and scheduling are 1) the Flight Series Schedule and 2) the Observing Schedule.

5.1.5 New Science Instrument Call and Selection

Periodically NASA will issue a call for new U.S. SIs, nominally every three years. There will be a separate process in Germany to develop new instruments. Announcements of Opportunity

(AO's) for U.S. SI development and upgrade will be issued and peer-reviewed by a process led by NASA Headquarters. After selection, the development of s new instruments and upgrades will be managed by the Observatory Systems Director..

The types of instrument investigations solicited are as follows.

- FSI Investigations: An FSI investigation is a science investigation that includes the development, delivery, and commissioning of a SOFIA facility instrument.
- SI Upgrade Investigations: An SI upgrade investigation is a science investigation that includes the upgrade, delivery, and commissioning of an existing SOFIA instrument.
- TDSI Investigations: A TDSI investigation includes the development and operation of an SI for the purpose of maturing and demonstrating new capabilities and methodologies of value to SOFIA and future NASA missions.

NASA Headquarters is responsible for the review and selection of science instrument proposals. The overriding consideration for the final selection of proposals submitted in response to this solicitation will be to maximize the scientific return and minimize the implementation risk while advancing NASA's astrophysics goals and objectives within the available budget for the SOFIA program. This includes an appropriate balance between the immediate scientific return from FSIs and the future scientific return, which is enabled through TDSIs. It is generally planned that two proposals will be accepted for each SI AO, with a planned cadence for making new SIs available to the Observatory at one every 24 to 36 months.

5.2 Observatory Certification and Commissioning

5.2.1 Aircraft Airworthiness and Certification

NASA Armstrong will certify SOFIA airworthiness according to the NASA airworthiness certification and flight test program currently being directed by Armstrong Flight Research Center.

NASA Procedural Requirements Document (NPR) 7900.3B, Chapter 2 ***Airworthiness and Maintenance*** directs that the Center Director has the responsibility to establish and approve airworthiness, flight safety, mission readiness, to ensure safe flight operations, to manage and thoroughly document aircraft configurations, and to ensure that flight objectives satisfy programmatic requirements. They also shall ensure that these procedures are incorporated into the contracts of those who operate and maintain NASA aircraft.

Additionally, the Chief of Safety and Mission Assurance formulates NASA safety policy and provides independent oversight of NASA aviation safety and safety procedures or guidelines that the individual centers follow.

At the Armstrong Flight Research Center, the requirements for airworthiness established in NPR 7900.3B, Chapter 2 ***Airworthiness and Maintenance*** are implemented in the Armstrong Handbook (DHB) X-001 ***Airworthiness and Flight Safety Review, Independent Review, Mission Success Review, Technical Brief, & Mini-tech Brief Guidelines***. This document outlines the type and complexity of oversight reviews that are conducted. The center chief engineer decides the appropriate level of review based on the complexity and risk associated with a particular set of missions, or following significant configuration changes of the aircraft and/or observatory. Approval to proceed with one or more flight series is documented with a flight request form that is signed by the AFSRB board.

Additional details of aircraft airworthiness and certification processes can be found in the Airborne Platform Configuration Management Plan, APP-DF-PLA-PM03-2006.

5.2.2 Science Instrument Airworthiness and Commissioning

Prior to science flights, all SIs must go through airworthiness certification to ensure safety in flight and a commissioning process to verify and validate the SI in order to make it available to GIs for observations.

The Science Instrument Airworthiness Team (SIAT) is a group of engineers within the SOFIA Program that reviews the instrument for airworthiness. The SIAT members consist of specialists from NASA, and include: flight operations engineers, structural engineers, system safety personnel, quality assurance representatives, and flight systems engineers. The airworthiness process is described in the SI Developers;' Handbook, SCI-AR-HBK-OP03-2000. The SMA and Airworthiness Certification requirements that are verifiable (i.e., those for which specific objective evidence of verification closure are required) will be found within the SOFIA Science Instrument System Specification, SOF-AR-SPE-SE01-2028.

The FSIs must complete a commissioning process prior to becoming available to GIs for SOFIA observations. This process requires a detailed Instrument Commissioning Plan (ICP) that describes the instrument-specific plan for commissioning. In general, the plan will include all of the ground and flight tests that must be completed to verify and validate the SI requirements.

FSIs are prepared for the commissioning flights and operated during the commissioning flights by the instrument team. Ownership of the FSI is passed to the SOFIA Program following the successful completion of the instrument acceptance review. The documentation required for the SOFIA Program to maintain and operate the FSI will be delivered prior to the instrument acceptance review. Instrument delivery includes the instrument control and data analysis pipeline software, as well as the associated operating manuals. SSMO is responsible for the operation and maintenance of the FSIs following acceptance and making them available for use by SOFIA GIs.

Instrument Teams providing PSIs are responsible for the development, delivery, and commissioning of the instrument.

TDSIs are prepared and operated by the instrument team for all flights, commissioning, and science.

Both PSIs and TDSIs must comply with the airworthiness requirements set by the SOFIA Program.

The SOFIA Program, based on the instrument availability and Observatory availability, will schedule the instrument commissioning period.

The Instrument teams should develop a commissioning plan that minimizes the time required for testing on the aircraft and in flight, while fully characterizing instrument performance and testing all user-supported instrument modes. The number of commissioning hours is nominally assumed to be 30 research hours. The commissioning plan should justify the number of commissioning hours requested and interval between flights.

5.2.3 Observatory Configuration Control

The SOFIA Program office is responsible for implementing the SOFIA Program Configuration Management Plan (CMP), SOF-DF-PLA-PM03-1054, which establishes the overall plan for the Configuration Management (CM) of the SOFIA System, Sub-systems, Computer Software Configuration Items and Hardware Configuration Items (CIs) during the system life cycle of the SOFIA Program. The plan addresses CM for those items defined above as Configuration Control end-items (i.e., Observatory System, Sub-systems, and CIs and associated baseline documentation) and Documentation Control.

The Airborne System Operations Director is responsible for maintaining configuration control for the modified aircraft and mission systems element of the SOFIA Observatory and supporting ground systems. This process was established during development and will continue for the life of the program. Details of these processes can be found in the Airborne Platform Configuration Management Plan, APP-DF-PLA-PM03-2006.

The SSMO Director is responsible for maintaining configuration control of the SSMO aspects of the Program. Details of these processes can be found in the Configuration Management Plan, SCI-AR-PLA-PM03-2001.

5.2.3.1 Change Control Process

Any change to a product (i.e., hardware, software/firmware, design documentation, hardware in the loop simulation, software in the loop simulation, critical process, etc.) baseline shall require a Configuration Change Request (CCR) to implement change. Also the implementation of any change to any baselined Airborne Platform system or simulation requires approval by the Project Control Board (PCB). Changes requiring a CCR include the following:

- Changes in requirements specifications and implementation;
- Changes in any hardware or software
- Improvement to any interface or interoperability
- New capabilities
- Change requests will be evaluated on a cost-benefit basis considering the following:
    - Life-cycle cost or savings
    - Schedule impacts
    - Feasibility
    - Additional impacts:
        - Identification of all known or potential adverse effects introduced by the change request, such as but not limited to: reliability, operational life, power consumption, communications protocol, interchangeability, performance, safety/hazard, etc.
        - Effects to next or interfacing assemblies/systems.
        - Verification and validation testing requirements
        - Required documentation changes

The PCB approves, disapproves, or returns for reconsideration the submitted CCRs for further analysis. When the CCR is approved, it will be assigned to a responsible engineer or organization for implementation.

5.2.3.2 Configuration Management

SOFIA has established the Windchill tool for managing documents and the associated CM records. When a document is submitted for approval, it is uploaded to Windchill, where the version is then tracked and maintained. Additionally, The Program has provided the SOFIA Portal, which among other things provides a means for searching and accessing documents in Windchill.

MOPS use the Concurrent Versions System (cvs) tool to manage the configuration of their data files and software builds. MOPS also use cvs for flight planning and execution product generation and maintenance.

5.2.3.3 Discrepancy Reporting

All discrepancies to existing requirements, processes and procedures will be documented on a Discrepancy Report (DR) Form and submitted to the appropriate Project Control Board (PCB) for analysis, tracking and resolution.

Discrepancies are classified by criticality level. Criticality levels give an indication of their importance. Definitions of the criticality levels are documented in the Configuration Management Plan.

The Mission Director (or designee) has the responsibility to ensure SOFIA systems discrepancies identified during science flight operations are adequately captured in the appropriate DR forms. Critical DRs must be reported prior to or at the post-flight briefing to assure that they can be worked as soon as possible.

The Pilot in Command (or designee) has the responsibility to ensure aircraft discrepancies that are identified during flight operations are adequately captured in the the NASA Aircraft Management Information System (NAMIS). Items entered into NAMIS must be appropriately dispositioned before the aircraft is allowed to launch the next mission.

SOFIA has established the JIRA tool to track and disposition DRs. Access to this tool will be made available on the aircraft to facilitate capture of DRs.

5.3 Flight Series Preparation

About 2-3 months before a flight series approaches, the operational groups will commence with the detailed planning and preparation necessary to conduct science missions for a given flight series. For MOPS, this will involve taking the cycle-based plans and turning them into detailed plans, procedures, and scripts for that particular series and all of the flights in that series. SciOps will work with MOPS to ensure the observation plans are turned into the actual observing plans and scripts to successfully acquire data. The SI team will prepare the SI by accepting it at DAOF, checking it out in the SI labs, and installing the SI on the aircraft. AOPS will prepare the aircraft and assign aircrew for a given series.

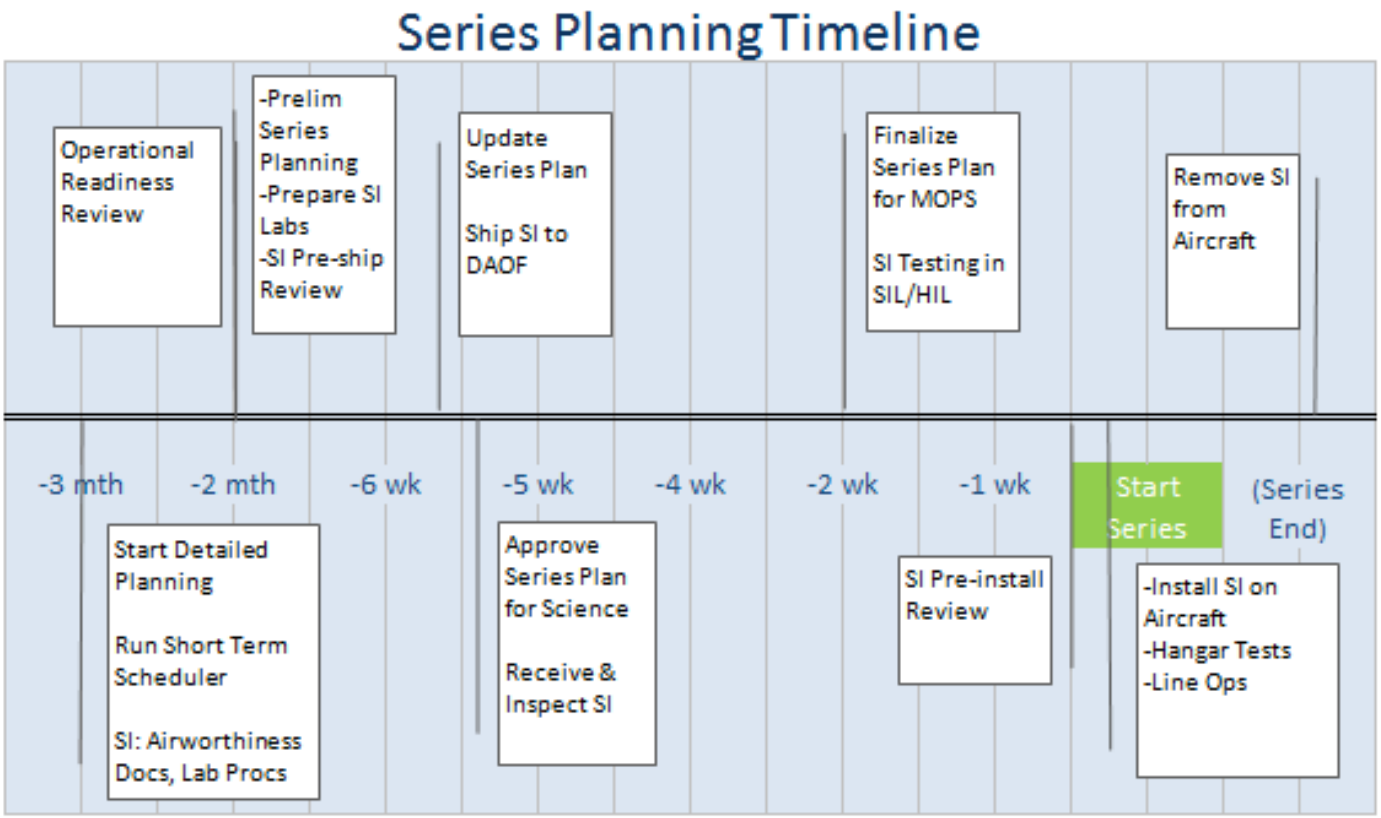

Figure 9: Series Planning Activity Timeline

Note that all of this preparatory work for a given flight series is likely to occur during preparations for yet other flight series and while science flights for another flight series are in progress (see Figure 8 in Section 5.1.1.2.

5.3.1 Pre-Series Planning and Scheduling

The goal of the pre-series planning and scheduling activities is to refine the cycle-based plan and schedules (see Section 5.1.4) for a given series into detailed products for that series and its component flights. The pre-series planning and scheduling activities are generally done once for each series, 2-3 months in advance of the first associated flight in the series.

The major product for a given series is the Series Plan, while the main product for each flight is the Mission Plan. Each of these major products consists of several individual products.

Using the Flight Series Schedule and the Observing Schedule as inputs, Mission Operations uses those products pertinent to a given series as guidelines to better define the series details. The first step is to work with the relevant IS to define the detailed astronomical observation request (AOR) information for each target to be observed during the series. Based on this information MOPS generates the main series-specific product, the Flight Series Plan.

Each Series Plan consists of:

- Pre-series Science Flight Plans – The SFP uses the Short-Term Scheduler to fold in the AOR information to refine the Observation Schedule into detailed pre-series flight plans; this may include adjusting and/or shuffling targets as needed between flights and/or series, in order to best carry them out. From an AOPS perspective, the Pre-Series Science Flight Plan defines the flight track or route, science leg sequence and durations, altitudes and total fuel required. They serve as the first hand-off of science plans for the coming series to AOPS. Pre-Series Flight Plans are revised and updated as necessary as the flight series' schedule evolves and based on aircraft operations (pilot) inputs on the proposed route and flight profile.
- Observing Plans – Upon completion of the pre-series science flight plan, the Telescope Operator (TO) generates an associated Observing Plan (distinct from, but based upon the Observation Plan from SciOps) that provides the detailed step-by-step information required for in-flight execution of each observation.
- Operational Procedures or Checklists – For example, procedures for SI installation
- Observatory Configuration – Defines how the observatory must be configured – SI, TA systems (e.g., secondary mirror and button, spider covers, tertiary mirror, gate valve, tub vacuum, counter-weight rack), and cabin (e.g., SI racks, workstations) for each series.
- Staffing – The MOPS Manager selects the MOPs personnel who will be a part of the flight series and creates a file to identify and document the primary/ backup mission crew members in each flight role.
- Baseline Flight Datasets (i.e., MCCS, MOPS) – A baseline set of all the series-specific operations files, along with any needed modifications to system configuration files, are transferred to and installed on the aircraft for the series.
- Special Considerations – This area may include notes and lessons learned from previous flights using the particular SI, recent upgrades to SIs, or other miscellaneous information useful for this flight series.

At six weeks prior to a given flight series at the SI Pre-install Review, the Flight Series Plan undergoes review and approval by the NASA Program Office. The Series Plan will continue to be updated until about two weeks prior to the start of the series. At this point, the Pre-Series Science Flight Plans are handed off from MOPS to AOPS. From this point up to the day of the flight, AOPS and MOPS collaborate to develop the final flight plans in their respective flight planning software, with AOPS' software generating the flight plans that are eventually filed with the FAA.

5.3.2 Mission Planning

The Mission Plan documents the scientific purpose, scope, assumptions, and prerequisites for a single SOFIA flight from the perspective of MOPS. An Mission Director (MD) will be responsible for each flight and will use the Mission Plan to define any required operations. A SOFIA Mission Plan contains six components:

- Science Flight Plan(s) - The Science Flight Plan provides the link between the flight profile necessary to conduct the planned observations and the course plotting data needed for the pilots to command the aircraft. It consists of three major components: a map of the planned aircraft tracks, the specific components of the Mission Plan for the current flight, and weather data. These are revised and updated from the Pre-Series Flight Plans as the flight series' schedule evolves and based on aircraft operations (pilot) inputs on the proposed route and flight profile.

- Observing Plan(s) - Provides the detailed step-by-step information required for in-flight execution of each observation.
- Operational Procedures and Checklists
- Observatory Configuration - Defines how the observatory must be configured – SI, TA systems (e.g., secondary mirror and button, spider covers, tertiary mirror, gate valve, tub vacuum, counter-weight rack), and cabin (e.g., SI racks, workstations) for each flight.
- Crew Manifest - The MD creates this file to identify and document the primary/ backup mission crew members in each flight role.
- Flight Dataset Overlays (i.e., MCCS, MOPS) – Overlays are added to the baseline flight datasets. All flight-specific operations files, along with any needed modifications to system configuration files, are transferred to and installed on the aircraft via the light overlay datasets.

The Mission Plan includes a checklist that allows the MD to verify that all of the required planning, preparation, and execution steps have been completed. It also documents any constraints affecting the flight such as cavity door range, cavity cool-down, and aircraft altitude. The Observing Plan defines the types of targets, both for calibration and observation, which will be observed during the flight. A timeline for the mission and the aircraft configuration are included in the plan.

The following is a timeline of major activities in the week before a flight:

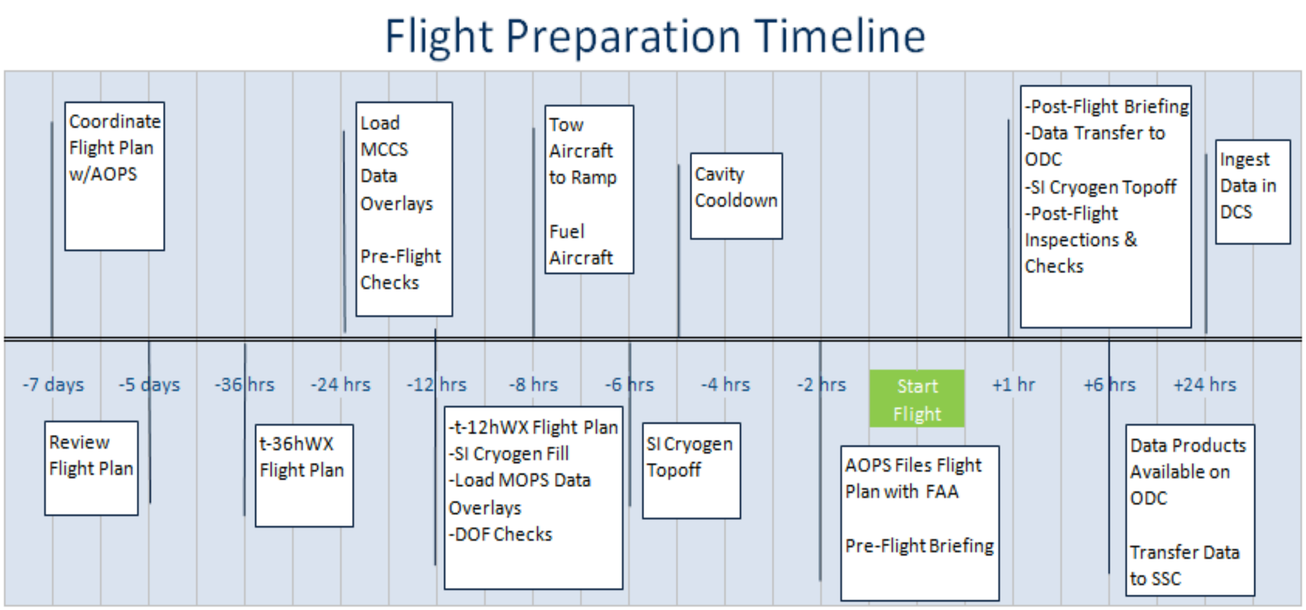

Figure 10: Flight Preparation Activity Timeline

5.3.3 Day-Of-Flight Flight Planning

Day-of-flight flight-planning is a collaborative effort by SciOps, MOPS, and AOPS staff. In order to proceed to this step, winds-aloft and atmospheric water vapor content forecasts must have become available. In the case of GIs using PSIs for their observations, hand-off for this final step in the planning process will be given to SSMO staff.

Development of the day-of-flight Flight Plan serves as the hand-off to AOPS for filing with the FAA and for loading into the Flight Manager. This step will be completed no later than two hours prior to flight.

The day-of-flight Flight Plan is loaded along with the flight datasets and is utilized by the MD to monitor activities. This Flight Plan serves as the baseline for any required in-flight re-planning.

SSMO will be evaluating the effectiveness of creating multiple day-of-flight plans to account for unforeseen Observatory aircraft departure delays.

5.3.4 Science Instrument Installation and Checkout

5.3.4.1 Pre-Installation Preparation and Checkout

MOPS leads the SI installation and configuration effort with support from AOPS and the SI Team. Installation of an SI on the Observatory begins with instrument checkout and cooldown in an Instrument Readiness Room (IRR) at the SOC. From the IRR, an instrument may connect to the SOC SIL, which allows software testing with the instrument in the loop.

If required, the Telescope Assembly Alignment Simulator (TAAS) is used to perform fit checks of SIs with a duplicate of the TA Flange Assembly that permits adjustment, checkout, testing, and characterization of SIs prior to installation and use aboard the Observatory.

Located in the Pre-flight Integration Facility (PIF), the TAAS aids in determining or verifying:

- The mechanical interfaces between the TA and SI
- The optical alignment, focus, and boresight of the SI with the telescope

The SI Team performs warm and cold functional tests, as well as a vacuum leak check and software interface verification to the MCCS approximately one week before installation on the aircraft.

Following successful lab checks of instrument, a Pre-installation Review will be conducted prior to installation to verify that all procedures are in place, ICD verification is complete and that the instrument is configured properly.

5.3.4.2 SI Installation on the Aircraft

After the SI has been checked out on the TAAS it will be installed on the aircraft. The removal of the previous SI typically will occur on the morning after its last flight (i.e., the morning of the previous Friday). The mechanical mounting of the SI on the TA will require the assistance of SOC mechanics (with the aid of an SI cart), but will be primarily the responsibility of the SI team, or in the case of a commissioned FSI, SSMO staff.

After mechanical installation is complete, the SI will be connected to all of its cables, hoses, and electronics. Cryogens will be filled as needed and vacuum pumps will be turned on as appropriate, placing the instrument in operational, flight-ready status. This entire procedure will take no longer than two to three hours, since it will have already been demonstrated in TA/MCCS simulation activities.

Once the installation is complete and the SI is operational, the TA will be activated and put through its balancing procedure, which typically takes less than one hour. Once TA balancing is completed an authorized inspector will conduct an airworthiness inspection of the setup.

Next, MOPS will conduct Integrated Functional Testing (IFT) while the aircraft is still in the hangar. The IFT requires the TO to set up and operate the TA, the Instrument Operator to set up and operate the SI, and ground support for SOFIA network configuration and power-up. During this test the SI configuration is checked and communication with the MCCS is verified.

If required (particularly for new SIs or upgrades), the instrument will continue checkout on the plane in the hangar or on the flight line with the telescope door open (Line Operations) to confirm alignment and proper instrument and software operation. First-time installation also will require Electromagnetic Interference (EMI) testing of all flight modes with aircraft systems.

5.3.5 Morning and Mission Briefings

Mission readiness will be reviewed on a flight-by-flight basis. Early on the day of flight the Aircraft Operations Manager will determine whether the Observatory is “mission capable” for that day’s mission during the Morning Briefing. This will be an evaluation of the Observatory airworthiness with respect to discrepancies on the aircraft, aircraft systems, and mission systems. The Aircraft Operations Manager also will consult with a representative of the MD to determine the status of the SI.

Prior to takeoff the Mission Director leads a mission briefing that is required for all personnel who will fly onboard SOFIA during the mission. A role call is conducted to verify attendance of everyone listed on the crew manifest and the responsibilities of each person on the aircraft are reviewed. The pilots provide support to the MD and report any non-routine aircraft issues. A meteorologist reports on the weather predictions at takeoff, in-route, and at landing time. System readiness reports from each system lead are also presented. The MD decides whether or not the Observatory is ready to perform its science mission and signs off for mission readiness. The MD will evaluate inputs from the SI Team as to whether or not the SI and science team is ready, and the Mission System staff on whether the mission systems and staff are ready.

Mission readiness will depend on the status of the science instrument installed, the science objectives for the flight, the status of the telescope and related systems, and other factors related to the specific mission to be conducted. The MD also will review and approve the flight plan from the science and mission standpoint, and assure that any other mission-critical requirements are met. The MD will then inform the Operations Engineer who will approve the Observatory for flight and turn the Observatory over to the PIC.

5.3.6 Pre-Flight Preparation

5.3.6.1 Pre-Flight and Day-of-Flight Checkouts

Within 24 hours of each scheduled flight, AOPS and MOPS personnel will perform pre-flight aircraft, TA, and Mission Systems checkout procedures. Both the Crew Chief and an Aircraft QA inspector must sign off on the completed procedures. Detailed visual and/or operational inspections of both the interior and exterior of the aircraft will be conducted to assure that there are no defects that may cause issues during the flight. The pre-flight checkout also includes specific procedures for inspection of the aircraft avionics and instrumentation, mission systems, and TA. The Mission Systems Preflight Procedure powers, initializes, and verifies communication between the TA, MCCS, and CDDS. Finally, all of the TA components are inspected for loose parts, missing fasteners, damaged or unsecured cables and connectors, and any fluid leaks. This includes a checkout of the TA cavity along with the mirror assemblies and imagers.

Just prior to moving the SOFIA aircraft out of the hangar, the final Day-of-Flight checkout procedures are conducted. The cockpit avionics are configured with the proper communication frequencies and the in-flight navigation systems are initialized. The Mission Systems are powered on and initialized, including the MCCS and crew workstations, the CDDS, and the CECS. The TA is also powered on and a final inspection of the cavity is performed before the cavity is sealed for flight.

5.3.6.2 Crew Brief

The crew brief involves only the flight crew. The Pilots, Flight Engineer, and Navigator meet prior to the flight to review the mission plan, discuss navigation routes, and review emergency procedures. The composition of the flight crew for each SOFIA mission is dictated by the crew duty time requirements in DOP-O-300. For a dual piloted aircraft like SOFIA, both pilots' duty days must not exceed 14 hours. If the mission requires up to 16 hours of crew duty time, a third pilot must fly. The same is true for the Flight Engineer, if the mission exceeds 14 hours, a second FE must fly.

5.3.6.3 Aircraft Launch, Recovery, Refueling and Towing

Several hours before flight, the SOFIA aircraft is towed out of the hangar into a position where the final flight checks and refueling are performed.. Aircraft launch, recovery, refueling and towing are detailed in the Armstrong Aircraft Maintenance and Safety Manual.

5.3.6.4 Flight Release

The final step before flight is to complete the Flight Release form. This is a signature record declaring the airworthiness of the aircraft and certifying that all maintenance issues have been resolved or otherwise addressed and that the aircraft is safe to fly for this flight. The form is prepared by the Operations Engineer and includes the pertinent information for the flight, such as date, time, flight plan, fuel load, etc. The aircraft Crew Chief, Operations Engineer, and PIC sign the Flight Release. An aircraft QA representative will provide a stamp indicating proper procedures were followed.

5.3.6.5 Emergency Coordination

Armstrong has well established emergency response capabilities defined in accordance with NPR 1040.1, NASA Continuity of Operations (COOP) Planning Procedural Requirements, and which address the range and scope of potential crises and specific response actions, timing of notifications and actions, and responsibilities of key individuals. The details of the SOFIA-specific emergency response can be found in the Program SOFIA Program Mishap Preparedness and Contingency Plan SOF-DF-PLA-OP05-2000. This plan outlines the initial response responsibilities, notification process, points of contact, aircraft hazards for first responders, evidence protection, and communication processes.

5.3.6.6 Airfield Coordination

SOFIA Operations Center at Palmdale:

- Facility leased by Armstrong Flight Research Center.
- Armstrong aircraft operations processes are in use for ramp and hangar.
- The Palmdale Facility is resident at the Plant 42 airfield.

Airfield, Plant 42:

- Owned and operated by Air Force (Wright-Patterson Air Force Base, Ohio).
- All aircraft fire and emergency provided by Plant 42 Fire and Rescue.
- Building fire and personnel emergency provided by Los Angeles County.
- Control Tower is operated by the Federal Aviation Administration.
- Control Tower hours of operation are 0530 – 2200.
- Operations between 2200 and 0530 are allowed in accordance with FAA regulations.

The Armstrong Memorandum of Agreement (MOA) with the Air Force for use of Airfield and services was signed and is in effect as of September 2009.

5.4 Science Mission Operations (MOPS)

With all of the preparation described in Section 5.3 (Flight Series Preparation) completed, SOFIA is ready to conduct a science mission flight. The first subsection 5.4.1 outlines a typical 10-hour mission, while 5.4.2 describes the execution of a mission from takeoff, through science observations, to landing and finally the immediate post-flight activities (further post-flight activities are described in Section 5.5). The next three subsections discuss variations that may occur from a typical mission in the form of Daytime Flights (5.4.3), Deployments (5.4.4) and Targets of Opportunity (5.4.5).

5.4.1 Typical Mission

The objective of a typical mission is successful execution of the flight plan and the associated observing plans. The TO, scientists and SI operator, MD, and pilots work in concert with the onboard observing systems to capture sufficient data of all planned targets with minimum deviation from the flight plan.

The typical flight profile is depicted below.

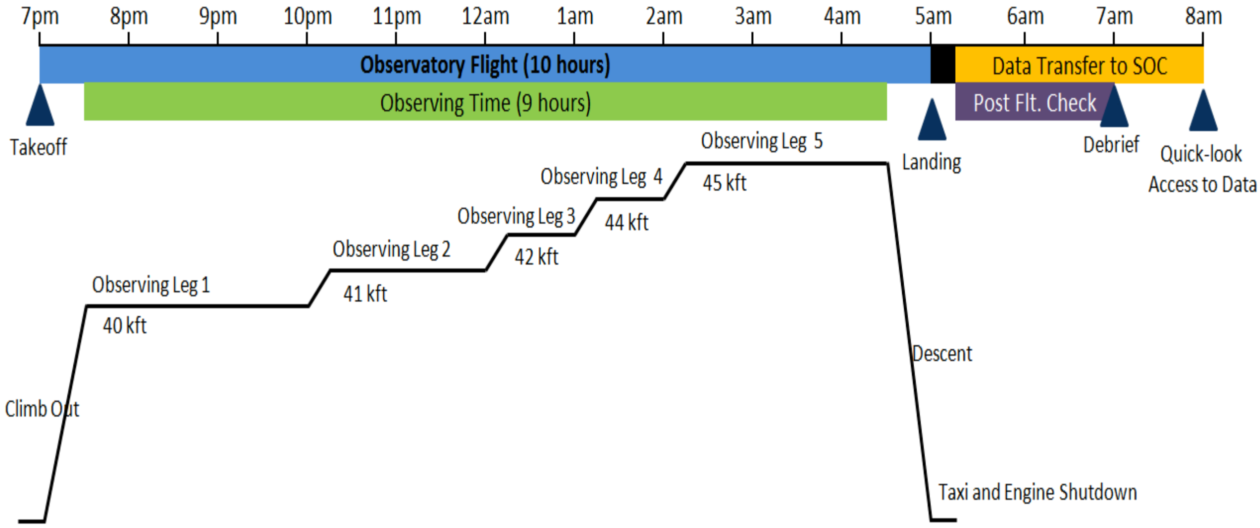

Figure 11: Observatory Flight Profile (10 hours)

The typical flight begins with a departure after nightfall and concludes with a landing before sunrise the following morning. The flight consists of a sequence of observing legs, each on a particular set of astronomical targets. As the aircraft burns fuel and concludes an observing leg, it typically climbs in altitude, where better science data may be obtained due mainly to less water vapor. Observing legs can vary in extent, from about 10 minutes to 4 hours each, subject to altitude constraints. The number of observing legs will vary in accordance with the observing plans to be executed during the flight. The number of astronomical objects that can be observed in one flight can range from roughly 2 to 16, but with an average of about seven.

A typical flight lasts 10 hours, with nominally 8.25 hours available for observing time, assuming the required systems are all working satisfactorily (see specific definitions of Research Hours and other metrics in Section 2.7.2).

Normally at least one celestial object targeted in a flight is a designated calibrator. The calibrator is a well-characterized object, so its measurement will calibrate the data for the entire flight. Without this calibration, observations will be relative, without absolute values, reducing their scientific value. The number of calibrators, tuning, etc. depend on the SI and are dictated to MOPS by SciOps as flight plan rules.

5.4.2 Flight Sequence

The flight sequence proceeds as the Observatory first takes off and ascends, arrives at the appropriate altitude to open the cavity door, acquires and tracks the first object, and executes flight legs and the associated transitions between flight legs. At the conclusion of observing the Observatory and crew implement the SI and telescope shutdown procedures, close the cavity door, descend, land and complete the remaining flight procedure steps. Once on the ground the collected science data is offloaded and the aircraft processed for post-flight.

Tow, Taxi, and Power Transfer

When the SOFIA aircraft is parked in the DAOF hangar it has power provided from the facility power source. Prior to towing the aircraft outside for final flight preparations, the facility power is disconnected and the aircraft remains without power for approximately 30 minutes while it is towed. When the aircraft is positioned for flight, the Auxiliary Power Unit (APU) is started to provide onboard aircraft power. All Mission Systems are then powered and remain operational for the entire flight. At the time that all mission personnel are seated on the aircraft, the inboard engines are started and the power source is transferred from the APU generator to the engines.

The PIC will request departure clearance from air traffic control and will taxi to the runway once authorization is received. While taxiing, the flight crew will perform additional checks including the flight controls and aircraft control surfaces.

Takeoff and Ascent

The initial climb out phase of the flight begins immediately after takeoff. During this time, MCCS computers are on and in use, and aircraft, SI, and TA systems are monitored. The TA is caged and the cavity door is closed.

The mission crew will activate any remaining MCCS components and complete their checkout. The SI and its data acquisition system are fully activated. During ascent, the aircraft begins its flight plan to position the Observatory for the first science observation leg.

After the science team has confirmed that the SI is ready for observing, the TO will move the telescope to the elevation of the first object, in accordance with the observing plan. The TA will be un-caged and its balance checked.

Typically the cavity door will be opened at about 35,000 ft, about 30 minutes after takeoff. Once the cavity door is opened, the gate valve is opened to provide a clear optical path between the SI and the sky.

Observing Legs

The first observing leg commences as soon as the aircraft has turned on heading and has wings level. It ends when the TO returns the TA to local stabilization mode for the aircraft turn to the next leg. During typical observing legs the TO will execute the setup procedure before handing off control of the TA to the SI team, which commands the TA via SOFIA Command Language (SCL), normally by executing SCL scripts.

During observations, the science team will setup and record science data in integration sets; the investigator team also will monitor the incoming data from the SI and work with the TO to assure that optimal telescope settings and commands are achieved and executed. Based on the data and observing results the team may decide to change the observing strategy to optimize science return.

During an observing leg, the TO is working closely with the science team with the setup of the telescope for their observation integrations and is monitoring all telescope systems. After the initial setup of the observing leg, the MD will help coordinate the onboard Education and Public Affairs programs with the science program. Within limits to protect the scientific productivity of the observatory, educator and media guests will be able to interact with the scientists and become familiar with the data acquisition process and the science questions being investigated. The MD will monitor all aspects of the mission and the mission system with an emphasis on flight safety (e.g., power consumption levels, telescope motion). To the extent possible, this monitoring will be automated, where if a system parameter approaches or exceeds a limit, a warning is given to the MD and the TO. Mission Ops crewmembers maintain an integrated mission log of comments that are collected in MCCS and provide a written record of flight activities. If flight path or aircraft altitude changes are required, it is the MD who negotiates the change with the flight crew.

Transition between Flight Legs

As the first observing leg is close to concluding, either the MD or a "time remaining on leg" indicator in the flight execution software will inform everyone. Once planned observations have been completed, the TO will return the telescope to the local stabilization mode to initiate the "transition between flight legs" phase.

The transition between flight legs begins when the TA is returned to local stabilization mode at the end of the previous flight leg and ends about 5 minutes later after the aircraft has turned on to the new flight leg and is flying with wings level. At this point the MD will ensure that the TA is in local stabilization mode and communicate with the flight crew to coordinate the turn.

During the turn, the science team is readying for the commencement of observations. The SI team will configure the SI for the coming observations and the GIs who are controlling the observing strategy prepare to direct the observations.

The next leg is setup and executed, with the remainder of the flight proceeding in this way, until the end of the last observing leg.

Flight Conclusion

Once observing is completed and the descent begins, the final wrap-up activities must occur, including centering and caging the TA, closing the cavity door, and making final entries in the mission log.

Post-Flight Activities

Aircraft personnel will go through aircraft recovery procedures as specified in 747SP documents and checklists.

The following aircraft activities occur as part of the post-flight timeline:

- Aircraft landing and taxi
- Aircraft parked
- Contingency: transfer to ground power
  - After landing and taxiing, ground power carts will continue to supply power to aircraft after engine shutdown
- Engines off, begin tow to hangar
- Flyers egress, handover to ground crew
- Post-flight debriefing(only if an early return to base was required)

  Ground crew continues to run the Cavity Environmental Control System for several hours to prevent water vapor in the air from condensing on the cold-soaked mirror surfaces.
- Complete aircraft tow-in to hangar

The following activities occur as part of the post-flight data transfers (see Section 4.5 for more detail):

- Data transferred from the aircraft's MCCS Archiver, which aggregates all of the Observatory data to be transferred, via a removable disk pack to the Observatory Data Cache (ODC) at SOC and then to the Data Cycle System (DCS) at SSC. Once the data is in the ODC it will be available for "quick-look" access to staff. This is further described in Section 5.5.

If this was the final flight in a flight series, which typically falls on a Friday, the SI will be removed the same day to prepare for the installation of the SI to be used in the next flight series.

Mission Debrief and Squawk Handling
Any aircraft issues will be briefed to the ground crew and entered into the NASA Aircraft Management Information System (NAMIS). This provides are solid documented configuration for the aircraft. Any entries identified by the pilots as "downing" squawks must be resolved and cleared before the next flight can be cleared to fly.
MOPS personnel also will perform squawk reporting, which encompasses the input of all reported in-flight squawks into the problem reporting system where they are then reviewed, prioritized, approved for work, assigned out for action, and ultimately tracked to completion. Any squawks requiring immediate resolution are prioritized by Mission Ops and issued to ground personnel to carry forward while the flyers conclude their day.

5.4.3 Daytime Flights

Current mission rules allow science flights with the door open during daylight hours, only under very controlled conditions,due to the potential damage to optical systems. However, there are rare opportunities when daylight flights may be valuable.

During daylight hours only very bright sources can be detected by the FPI. Therefore, daytime flights are only practical if: (1) the science source itself is bright enough in the visible spectrum to be used as the "guide star" for the telescope pointing loop; (2) there is a guide star close by which is bright enough in the visible during the day; or (3) the telescope pointing stability/accuracy can be relaxed.

Only rarely do any of these three possibilities occur, but they do occur. The most common examples of daytime missions are missions to observe solar eclipses and missions to observe Solar System bodies.

A daytime Science Flight not associated with a night flight will generally be much less than 10 hours in duration (about 5 hours or less) since, in general, only one science source will be observable on the flight. Daytime sources are usually self-calibrating by necessity, so no calibration leg is normally required.

5.4.4 Deployment Flights

Deployments occur any time the SOFIA aircraft is required to operate from an airfield away from the DAOF. This is typically due to a planned deployment to the Southern Hemisphere to observe the southern portion of the night sky. Deployments can also be the result of Target of Opportunity observations that may require flights conducted out of other locations or flights that begin at the DAOF and end at alternate airfields. Other events such as scientific conferences, air shows, Outreach opportunities, etc. may require deployments. The Deployment Planning Guides for New Zealand (SOF-AR-HBK-OP02-2176) and Germany (APP-DF-HBK-OP02-2100) may be used as a reference for deployment preparation.

5.4.4.1 Deployment Flight Series Preparation

The deployment process will be a “turn-key” operation, making it possible for a science mission to be planned to occur one day after the Airborne Observatory arrives at the deployment location. Once a deployment has been identified by the SSMO Director, has passed peer review, and has been scheduled by the Program Office, a small cadre of SOC staff, called the Deployment Group, will be formed. With representatives from all the SOC organizational groups relating to the deployment, this group will work closely with SSMO and will be responsible for the scheduling and planning of all activities relating to the specific geographic, science, and maintenance/ground handling mission requirements for a particular deployment. The deployment group is also responsible for developing procedures relating to specific deployment scenarios. The procedures will include: packing and shipping of deployment equipment and inventory (i.e., the deployment kits); the ordering and handling of special materials (in some cases hazardous) at the site required for both science and maintenance tasks; set-up of the mission facility site and accommodations for the deployment team; and emergency procedures.

A deployment begins when the Airborne Observatory departs DAOF for the deployment site and completes when the Airborne Observatory returns to DAOF.

5.4.4.2 Southern Hemisphere Deployments

Deployments will typically occur at the main deployment site in the Southern Hemisphere in Christchurch, New Zealand. This site is necessary since not all of the sky and infrared objects of interest are visible with flights from DAOF. Deployments to Christchurch are not “targets-of-opportunity” deployments, which are discussed in earlier and later sections of this document.

A two-week deployment to the Southern Hemisphere site is planned annually; these two weeks will likely occur in July due to target availability but is ultimately driven by the proposals selected.

The actual length and time of the deployment, which SI will be flown, and the types of observations to be made in the Southern Hemisphere will be selected by the normal Peer Review Process the year before; the results of this process are known to SSMO at least nine months before the start of the Southern Hemisphere deployment. The Deployment Team consists of the SOC and SSMO staff and outside scientists who are physically on deployment. The deployment team at any given time on a Southern Hemisphere deployment will typically consist of:

- 30 aircraft support personnel
- 8 aircrew
- 18 mission system personnel (including ground and 2 mission crews)
- 8-14 science instrument team memebers (including scientists from outside institutes)
- 14 TA support (DSI)
- 1 SOC manager
- 1 SSMO manager
- 1 DLR manager
- Outreach facilitators

A subset of this team will fly (commercially) to the deployment site about one week before the Observatory does. This subset will be called the Advance Team, and will consist of the flight and mission crew for the first flight of the deployment, and the ground crew required to: assemble the deployment ground support facility; meet the Observatory when it arrives; and ready the Observatory for its first Science Flight.

A deployment kit will be maintained at the DAOF for Southern Hemisphere deployments. This kit contains equipment to be transported to the deployment site to support SOFIA science operations and aircraft maintenance, such as tools, spare parts, and the telescope cavity cooling cart. The deployment kit will be configured to the requirements of a particular deployment, but much of the kit will be common to all deployments. Where possible, equipment will be stored at the Southern Hemisphere site permanently.

All deployment equipment must be classified and documented for export control requirements.

5.4.4.2.1 Deployment Timeline

The following graphic depicts the major activities associated with preparing for a deployment, starting nine months prior to the deployment.

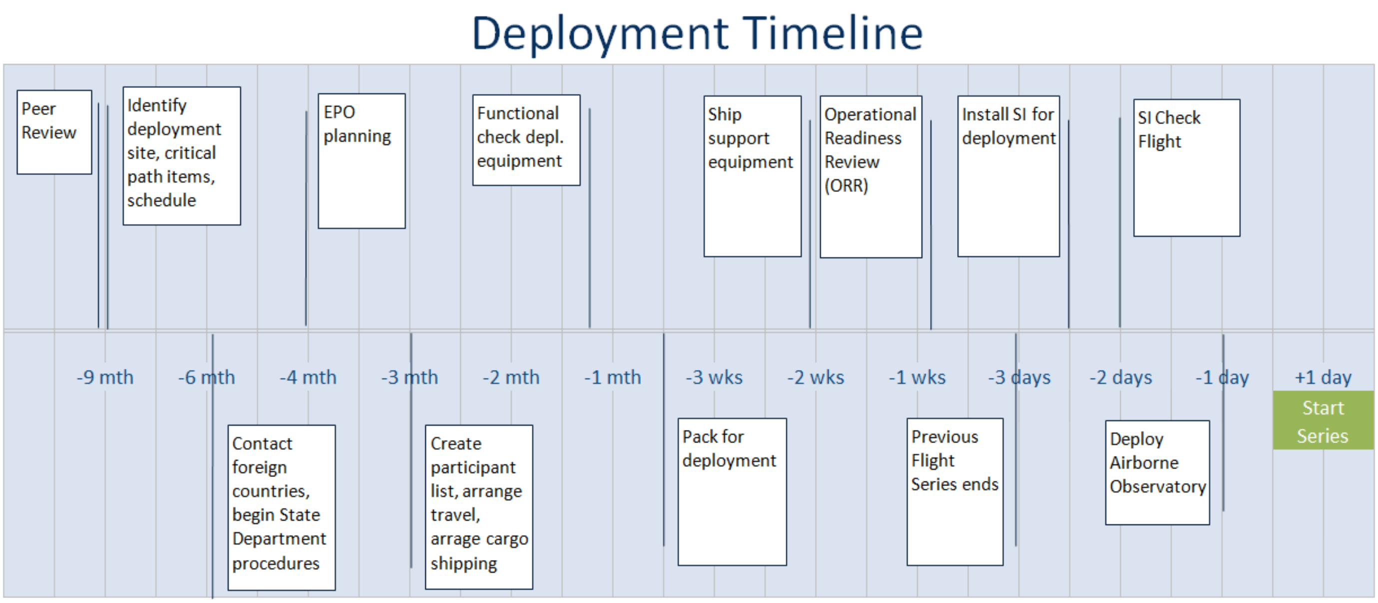

Figure 12: Deployment Timeline

5.4.4.2.2 Travel to and Arrival at Deployment Site

During the ferry flight or flights to the deployment site, there may be an opportunity to do some science observing. If science observing is to be done during a multiple ferry flight scenario there must be staff and equipment at the stopover point to keep the SI cold between flights.

Upon arrival at the deployment site the lead of the deployment team will take responsibility for the aircraft cargo manifests and clearance through customs. Each individual on the aircraft will have filled out their own customs forms, which were made available on board before landing. Advance arrangements will have been made at the point of arrival to facilitate passage through customs.

Depending on the location, the aircraft may have to be parked initially at the terminal or other locations to complete customs requirements and off-load crew. However, after arrival the aircraft should be moved as soon as possible to its work location at the airport. This will allow the unloading and setting up of the deployment site to begin as soon as possible by the Advance Team. The people who flew out on the Airborne Observatory will be resting at this time.

The advance deployment team will unpack and install equipment at the designated site. Servicing and operational checks will be performed.

Aircraft, mission systems, and the SI are readied for the science flight planned to originate from the deployment site for the next day. In cases where the schedule cannot be met, the deployment team lead will adjust the schedule accordingly, with inputs from the deployment team and staff at SSMO. As a rule, the flight schedule will be maintained (as it is at Palmdale), and no "make-up" flights will be scheduled.

5.4.4.2.3 Flight Series on Deployment

A flight series at the main Southern Hemisphere deployment site will mimic a flight series originating from Palmdale to the extent possible.

Daily maintenance of the Observatory while on deployment will be performed in time slots similar to those outlined for a flight series at DAOF. These maintenance items are pre-planned before the deployment, and the required inventory/equipment are sent to Christchurch from the DAOF or acquired at Christchurch (e.g., the leasing of aircraft equipment).

After the last flight of a deployment and all post science flight activity has ceased, the deployment team:

- Packs (including inventory) and makes shipping and customs arrangements.
- Arranges for storage of SOFIA equipment to be left in place for the next deployment.
- Readies and loads the cargo to be flown out by the aircraft for the flight back to the DAOF.

Preparation and planning for Observatory departure from the deployment site is finalized before the end of the last science flight by the deployment team and includes the required paperwork to meet customs requirements.

After the Observatory has departed, it may be necessary for a part of the deployment team to remain behind for a few days to complete shipping and other formalities.

5.4.5 Target of Opportunity Science Mission

Targets of Opportunity (ToO) are science observations associated with events that cannot be predicted in advance. ToO observations can involve known targets with unpredictable timings such as certain recurrent novae and targets that can only be identified by class such as supernovae or newly discovered comets.

There are two types of ToO:

Type I – submitted in response to a planned Call for Proposals and reviewed in the normal TAC process for a given proposal cycle. Allocations for Type 1 ToO Observations are set aside in normal scheduling, but the execution times are not known until the triggering event occurs.

When a triggering event occurs, the SSMO Director will determine whether SOFIA resources (instruments, staff, and observing time) can be diverted to support the ToO.

Type II – observations which cannot be planned for in advance and for which no proposal has been submitted. Type II ToO observing allocations come from DDT. The DDT review process evaluates requests for Type II. The likelihood of the acceptance of a Type II ToO will depend on the scientific merit of the observations, advance notice given, and the impact to the existing observing program.

ToO observations can be constrained by international clearance requirements or Canadian airspace flyover requirements, should the observations require.

5.5 Post-Flight Operations

5.5.1 Science and Engineering Data Handling and Management

The goal of data handling and archiving is to get all flight data products off of the Observatory, to get the quick-look data in front of the necessary users at SOC, and to transfer the data into their proper place at the SSC. The major products include mission results into the DCS archive, flight dataset "deltas" into the CM tool, and squawks (in-flight issues) into the problem reporting tool. These activities are typically done once per flight, the morning after landing.

These activities begin with identifying and transferring all flight data products off the aircraft and to the staging area at the SOC for transfer to the SSC. These data products consist of the following data types:

- Mission Systems data – These products come in three types:
  - HK – Engineering housekeeping (HK) data from the MCCS systems.
  - MADS – Recorded Mission Audio Data System (MADS) files from the four prime onboard audio channels.
  - TAIPS – TA Image Processing System (TAIPS) files written out by the TA's WFI, FFI, and FPI.
- Science data – This is the science data from the SI
- Logs and flight dataset "deltas" – These are any new or changed files in the flight dataset load areas, the so-called "deltas" or "as-flown" flight datasets.

The Information Technology (IT) group removes the disk pack in the MCCS Archiver and hand-carries it to a comparable disk array at the SOC. Once the disk pack is connected to the disk array, the data is pushed to the Observatory Data Cache (ODC). The data on the ODC is made available for "quick-look" access for users at DAOF. Finally, the data in the ODC is transferred to the DCS at the SSC. The figure below shows a high-level depiction of this process.

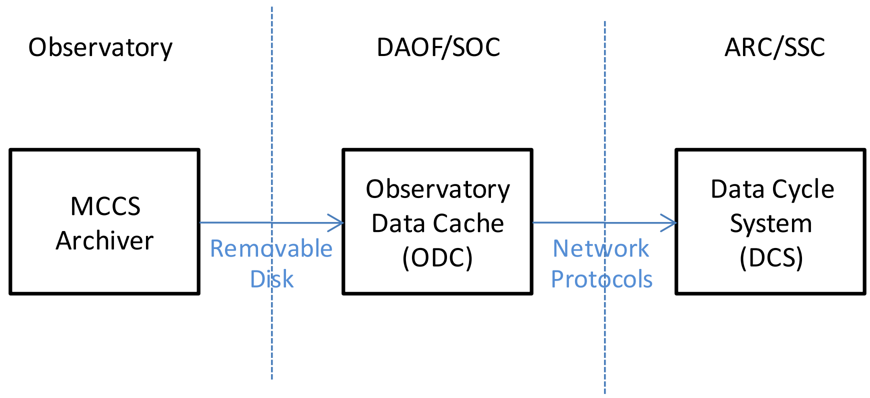

Figure 13: Post-flight data transfer from Observatory

Once all post-flight data products have reached the staging area at ARC/SSC, the Mission Operations team can begin the final data handling and archiving activities to review all products and place them in their final homes.

5.5.2 Science and Engineering Data Processing, Analysis and Access

Once the science and engineering data have been retrieved from the Observatory post-flight, the data undergoes a number of analyses and processing at different stages for different users. Science data is eventually published to the public in accordance with proprietary data policies dictating the length of time the data remains exclusive to investigators.

Data is required to be available for quick-look access with 3 hours after engine shutdown. The post-flight quick-look access to flight data will be accommodated by web-based access for authorized users to the stored data in the Observatory Data Cache (ODC) at DAOF/SOC. Several more hours will ensue before flight data is archived in the DCS archive at ARC/SSC due to transmission time over the data-link between DAOF and ARC/SSC and processing time at the DCS data staging area prior to ingestion into the DCS archive. Therefore, the ODC will serve as the source of post-flight quick-look data.

Tools will be provided so users (i.e., MOPS staff, GIs and Instrument Support Scientists, etc.) can access and retrieve selected data from the ODC, download the data to local computers, and analyze the data to diagnose flight anomalies. Early post-flight diagnosis of flight anomalies is imperative to determine problem root causes and determine possible resolutions. If not resolved, the Observatory deficiency could result in alteration of the observation plan for the next flight or in the worst case, scrubbing of the next flight. Observers are permitted to copy data onto portable media from the ODC.

Flight data transferred from the aircraft to the ODC is subsequently transmitted over the data-link from DAOF to the DCS data staging area at ARC/SSC. After processing by Mission Operations staff, manifested science data is ingested into the DCS archive and Modstor mission_data files are saved to the Ops CM repository.

Post-flight access to SOFIA Observatory flight data from the DCS archive will serve multiple purposes and authorized users to include:

- GI teams for science data analysis
- Running science data pipelines to produce processed and calibrated science data sets

- MOPS staff for anomaly diagnosis and Observatory trending
- TA staff for telescope anomaly diagnosis and trending
- SOFIA NASA management for Observatory performance trending and reporting
- Other public users (after proprietary data periods expire) for archived observation data

Data archived in the Data Cycle System (DCS) at ARC/SSC can be accessed and retrieved by registered users via the main DCS website; http//dcs.sofia.usra.edu. Once on the website, the user can search the DCS archive and get a table of summary data based on the entered search parameters.

Then the user can identify any files of interest and request the data (requires a DCS login). The requested files are bundled, placed on a public FTP site, and an email sent to the user with a link to the bundled data files. Once the data is received the user will utilize a variety of tools to extract data items of interest to analyze.

5.5.3 Summary Flight Reports

SSC staff will issue regular flight reports based upon the housekeeping data recorded during flights on the MCCS and transferred to the SSC archive. These reports will include data that will confirm proper performance of Observatory systems. Trending results may indicate the need for procedural or system changes to the Observatory. Trending would also be frequently used to understand how environmental conditions such as aircraft positions and attitude, or TA temperatures may have affected operations of the Observatory or the quality of science data.

Specific examples of trending use include:

- Plot altitude, latitude, longitude and true heading versus time to confirm the altitude that science data was acquired on each leg of a flight.
- Plot TA cross-elevation and true heading versus time to determine how heading changes affected telescope position in the cavity.
- Correlate TA cross-elevation, line-of-sight, elevation and true heading values for a flight to determine the likely cause of unexpected losses of telescope pointing control.

SSC staff will utilize available extraction, analysis and plotting tools to develop and implement a standard set of Observatory items to trend. The provided tools will allow extraction from the archive of a full set of flight housekeeping data items that will be transferred to a shared disk area accessible to SSC staff. The standard trending set will then be generated to produce commonly desired plots and lists of item values versus time and then posted to the webpage(s) for each specific flight. Interested parties are then notified via email or webpage posting that flight housekeeping data is available.

Trend data for each flight will be accumulated for further trend analysis to detect degradation or improvement of Observatory performance over time.

In addition to the standard set of Observatory trend items, other interested parties (including SSC and SOC staff and science users with access to SSC computers) can run the available tools to analyze and trend additional Observatory data items not part of the standard set.

5.5.4 Science Data Pipelining

Science data pipelining is the processing, or reducing, of raw science data into products useful to Observatory users. FSI teams deliver the software pipelines as part of the acceptance package, at which time the pipelines are integrated into the Data Processing System (DPS).

There are three levels of science data, in order of their degree of processing:

- Level-1 data are raw data produced by the instrument.
- Level-2 data are processed using algorithms specific to the instrument such that the new data products are free from instrument-specific artifacts and are in units proportional to the flux of the astronomical source.
- Level-3 data are the same as Level-2 data, but calibrated into physical units.

5.6 Observatory Maintenance

Observatory maintenance is required in order to maintain operation of SOFIA over its 20-year lifetime. Maintenance occurs in the major areas of the Aircraft, Mission Systems, the TA, and the SIs. Aircraft maintenance is the primary schedule driver of other maintenance activities, as it requires periodic science flight downtimes during a calendar year.

5.6.1 Aircraft Maintenance

Aircraft maintenance is performed under the guidance of the SOFIA Platform Project Maintenance Plan (APP-DF-PLA-PM01-2004). The authority to perform maintenance and to assure airworthiness of Armstrong aircraft is delegated to the Flight Operations Directorate from the Director of the AFRC. The Flight Operations Directorate utilizes a combination of NASA civil service and contractor personnel to ensure that aircraft maintenance complies with all NASA and FAA regulatory requirements for maintenance intervals, tasks, and processes for the Airborne Observatory. In order to meet the demand for science flight hours at FOC, maintenance personnel will work a rotational 3 shift operation seven days a week. Flights are generally scheduled on week days and weekends include aircraft and TA maintenance/squawk resolution, instrument swaps, and cryo fills.

Typical Boeing 747 aircraft operated by commercial airlines are flown far more frequently than the planned SOFIA utilization. As a result, SOFIA's estimated rate of utilization dictates that the intervals specified in the maintenance program are based more on calendar time rather than flight cycles or flight hours. Based on this, Armstrong Flight Operations has implemented a Low Utilization Maintenance Plan (LUMP), calendar-based maintenance program. The maintenance program tasks are based on the Boeing 747 Maintenance Planning Document with many of the required checks calendar-driven instead of hourly or cycle-driven.

Based on the required aircraft checks and the necessary intervals, the SOFIA Program sets aside a total of twelve weeks out of each year for planned maintenance. This time is divided into three, 4-week maintenance periods. Each of these includes three weeks for the required maintenance tasks plus one buffer week in which there may be a Functional Check Flight (FCF) to verify airworthiness after the completed maintenance.

There are five levels of planned aircraft maintenance checks: A, C, V, Heavy Maintenance Visit (HMV), and unique maintenance associated with the modifications required to accommodate the telescope installation, arranged in order of increasing interval between checks. Each higher-level check includes any lower-level check that may fall in the same time interval.

In addition to the planned maintenance checks, regular maintenance is accomplished progressively during normal maintenance hours (pre-, through-, and post-flight checks) and includes routine engine maintenance. Visual inspections of the fuselage and heavy wear areas of the cabin are conducted. Any filters and fluids that require servicing or replacement are maintained. The aircraft emergency equipment is checked and any necessary mission system maintenance is performed.

5.6.2 Mission Systems Maintenance

SOFIA Mission Systems include the MCCS, the Cavity Environmental Control System (CECS), and the Cavity Door Drive System (CDDS). All three systems will be maintained in a similar manner. . After electronic systems and spares are received, either from the manufacturer or the in-house instrumentation fabrication shop, the systems will be functionally tested in the SOFIA Hardware in the Loop Simulations (HILS). Once functional testing is complete, the spare units are stored in environmentally controlled areas.

The MCCS hardware will be upgraded as part of the continuous improvement program, which provides for major upgrades every five years. The MCCS software will be upgraded based on an annual assessment. CECS and CDDS will have hardware upgrades to their controllers and other components as required. Hardware and software upgrades for all Mission Systems will be planned to occur during aircraft scheduled maintenance downtimes. Maintenance tasks will be performed by NASA and/or contractor personnel at the SOC.

5.6.3 Telescope Assembly (TA)

5.6.3.1 TA Maintenance Plan

5.6.3.1.1 Scheduled TA Maintenance Activities

The maintenance group of the TA Team is responsible for conducting preventive and recurring maintenance activities. These activities are called “Maintenance Periodic Inspections (MPI)” by the TA maintenance group and ensure safety and airworthiness of the TA. These activities include visual inspections, functional checks, performance checks, leak, pressure and vacuum checks, lubrication and servicing and limited lifetime item changes. Periodic inspections are performed during the ground-time between 2 flights or during downtime phases. The TA Maintenance Plan will be adjusted to comply with the planned flight frequency of 4 flights per week.

There are different levels of scheduled maintenance activities. The most extensive activities are called “TA Heavy Maintenance” and are scheduled every 6 years.

The TA team follows the NASA Armstrong directions for airworthiness and implements these in their MPI activities of the TA.

5.6.3.1.2 Unscheduled TA Maintenance Activities

Unscheduled tasks are triggered by faults during operations during flight or on the ground or by findings during scheduled maintenance activities. These activities are called “Maintenance Fault and Repair (MFR)" by the TA maintenance group. The mission crew, the ground operations crew or the TA maintenance group, generates a fault report. The TA maintenance and engineering group's process the fault report and assign a criticality level as listed in the table below.

Criticality Level	Fault Effect	Remarks
Level 1	Aircraft on Ground	Fault poses a safety risk or prevents operation the TA; Problem has to be resolved before the next flight is possible
Level 2	Reduced observatory performance	Operation of the TA is possible with reduced performance; repair will either be done before the next flight or deferred to the next scheduled maintenance period
Level 3	observatory operations possible without loss of performance	Fault will be address during the next scheduled maintenance period

To reduce the impact of a fault in an electrical system on the flight schedule it is planned to transfer from a component level spare part and repair approach to a "Line Replacement Unit (LRU)" approach. If a fault is identified as related to a certain unit, this unit can be swapped and replaced with a spare unit. The faulty unit is then repaired without schedule impact. A LRU concept also mitigates the risk of delays, if a spare part is not in storage and has to be purchased first or if the spare part is obsolete and cannot be acquired anymore.

The TA team follows the NASA Armstrong directions for airworthiness and implements these in their MFR activities of the TA.

5.6.3.2 TA Upgrade Plan

There are 2 categories of TA upgrades:

- Upgrades to improve the TA performance or to add new capabilities
- Upgrades to replace obsolete components

The TA performance will have to be improved over time to meet the expectations of the science community. Additional TA capabilities can make SOFIA more interesting for scientists and improve SOFIA operations. Upgrades that improve the TA performance and capabilities will be requested by the SOFIA Integration Office or proposed by the TA engineering group. The TA engineering group is responsible for the design of these upgrades.

Obsolescence of parts will become a more relevant problem for the TA. Most electrical systems are based on industrial applications where the life cycle of components is significantly shorter than in the aircraft industry. This will require periodic design modifications on TA systems to adjust to the available components. The TA engineering and the TA maintenance group will address these design modifications together with industry partners.

Upgrades will be implemented during scheduled Observatory downtimes.

5.6.3.3 Industry Support for TA Maintenance and Upgrade Activities

It is desired to have continuing support by the original developers of the different telescope systems. This shall ensure that non-standard maintenance activities that require special skills, fabrication of spare units and development activities for modification of existing TA systems and assemblies can be done in a cost-effective and timely manner with limited risk. It is planned to implement this industry support by support contracts and regular interaction with these industry partners.

However, it is also clear that this industry support cannot always be expected and relied on, since relevant personnel can be assigned to other projects, leave companies or companies themselves can change their business segments or go out of business. This has to be considered and reflected in schedule and cost estimates during planning of maintenance and engineering activities.

5.6.3.4 Mirror Maintenance

Periodic maintenance of the telescope's optical surfaces is required as dust and other contaminates accumulate in the course of normal usage. The cleaning of these optical surfaces can vary in complexity, depending on the degree of contamination, and the nature of the optical surface itself.

5.6.3.4.1 Mirror Inspection

The primary, secondary, and tertiary mirrors are periodically inspected in order to track defects from cleaning to cleaning and from recoating to recoating (also called aluminizing).

5.6.3.4.2 Mirror Cleaning

A very common method of cleaning aluminized or silvered optical surfaces is using CO2 frost (or snow). This method is recommended for surfaces which contain dust and has not adhered to the optical surface. This method is considered a "non-contact" procedure, since no human hand or tool touches the mirror surfaces.

When dust or dirt has adhered to the mirrored surfaces, the CO2 frosting procedure may not have much effect. Usually this happens when condensation has occurred on the mirrored surfaced, causing whatever dust or dirt to cement itself to the metal coating. At such times, a wet wash is required. If done *in situ*, appropriate measures are taken to isolate sensitive areas in which liquid could drain.

5.6.3.4.3 Mirror Recoating

The surfaces that are aluminized include the primary mirror, secondary mirror, and aluminized tertiary mirrors (fully reflective and aluminized companion to the dichroic). The tertiary dichroic has a gold coating, and must be contracted out when recoating becomes necessary. Due to the smaller sizes of the secondary and reflective tertiaries, these surfaces also are contracted out for recoating.

Recoating the primary mirror requires a critical lift, both for the removal of the tertiary mirror pedestal and for the primary mirror itself. The primary mirror, once removed from the TA cavity, is then transported to the MCF for recoating.

Once recoating is complete, the primary mirror then gets transported back to the aircraft, and is critically lifted into the TA cavity and the TA itself. The tertiary mirror pedestal is also lifted back into place. Finally, a week of telescope optical alignments begins to insure collimation of all the optical components. Including the critical lifts both out from and into the TA cavity, the stripping and recoating of the primary mirror will take up to 45 working days.

5.6.4 Science Instrument Maintenance

FSIs are maintained in accordance with the SOFIA Facility Science Instrument Maintenance Plan, SCI-US-PLA-PM17-2065. FSIs are kept at the SOC with onsite FSI maintenance engineers (part of MOPS) and IS support (SciOps) available from the SSC. The IS ensures that the instrument is functioning correctly for science flights and monitors instrument calibration and software (DCS) pipelines. The IS provides GI support before and during flights.

After each flight series the IS reviews instrument performance to ensure science quality and recommends effort required to maintain instrument science performance. Based on proposal cycle and instrument subscription, data quality and relevance, the IS can recommend an FSI be reviewed to determine viability and possible retirement.

The FSI maintenance engineers prepare the FSI for flights and participate in all pre-flight checks, FSI installation and verification, and post-flight checks. The FSI engineers maintain the FSI between flight series and work closely with the IS.

The FSI maintenance engineers work with A/C engineering and QA personnel to ensure continued conformity of instrument configuration to approved configuration control specifications. They also coordinate safety and integration activities with QA and Operations personnel.

Significant repair to an FSI may be handled through a contract with the original development team. Any changes to instrument design and/or operation documents must be reviewed and approved prior to the flight series in which the FSI is to be used.

PSIs are kept and maintained at their home institutions and are normally shipped to the SOC two weeks prior to flight series.

The PI Scientist and his/her team ensure that the instrument is functioning correctly for science flights. The responsibilities of the PI Team include:

- Preparation of the instrument at the SOC for science flights
- Monitoring instrument performance
- Archiving raw data
- Supporting GIs during execution of their approved proposal in its scheduled flight series
- Following observatory approved maintenance plan at their home institution
- Submitting engineering changes to instrument design/configuration data submitted to observatory team for review and approval as necessary.

The Instrument team, PI team, and observatory project personnel track configuration of each instrument between flight series. That oversight consists of:

- Tracking instrument status and noting changes in the instrument log book
- Implementing maintenance plans and procedures approved by observatory team

- Submitting changes to the instrument configuration affecting airworthiness to appropriate project personnel for review and approval.
- Presenting the instrument configuration review at the SOC prior to the flight series in which that instrument is to be utilized.

5.7 End-of-Program Disposal

5.7.1 Data Retention

End-of-life retention of science data is referenced in the Science Data Management Plan (USRA-DAL-1162-00).

5.7.2 Lessons Learned

SOFIA will actively participate in knowledge-sharing activities to ensure mission success and the retention of vital information and lessons learned as follows:

(1) Assume responsibility for gathering, organizing, and sharing knowledge.
(2) Host and attend knowledge-sharing sessions across organizations.
(3) Actively participate in knowledge activities in order to learn and contribute knowledge to the shared goal of mission success.
(4) Ensure that technical reports, data, or other means used to document knowledge are marked with respect to proprietary or export control restrictions and consistent with guidance set forth for SBU in NID 1600.55 at the time of generating those documents.

Upon program transition to ARC, the above practices shall use APR 7120.6 as a guide to establish cross program and oraganization lessons learned reveiws and incorporation of the LL in tnto the knowledge database. Lessons learned from development and operations at AFRC and DAOF shall be documented and retained in accordance with AFRC lessons learned policies.

5.7.3 SI Retirement

Retirement of SIs shall be primarily based on scientific productivity. FSIs can also be retired based on restructuring of the scientific priorities as defined by the NASA Strategic Plan. PSIs and TDSIs can also be retired based on excessive maintenance requirements.

Each SI should reliably contribute high quality science observations that maximize the scientific return of flight opportunities and the unique capabilities of SOFIA. Instruments that do not demonstrate sufficient science productivity will be removed from the suite of instruments available to the general observing community.

The retirement of SIs is necessary in order to keep the number of supported instruments available to the SOFIA observer community at a manageable level and to make way for new instrumentation by freeing up resources including funding, personnel, and flight hours. FSIs will be retired after a time at which the cost of their maintenance and support is no longer commensurate with their ability to competitively deliver science.

TDSIs are retired after two years from the date of the last flight of guaranteed observing time.

Each year, science and mission operations personnel, instrument scientists, mission directors, information systems and mission operations leads will summarize observatory performance and accomplishments, and report to the SSMO Director on the scientific and operational performance of each instrument. Instruments will be evaluated for overall science productivity considering the following:

- Performance, reliability and success on the telescope
- Maintenance and operations costs
- Proposal subscription rate
- History of publications that use data from the instrument
- Science capability compared with other existing observatories and platforms

An instrument will be considered for retirement if any of the following conditions apply:

- Instrument performance has degraded significantly from original capabilities
- Instrument has failed and requires costly repairs
- Instrument reliability significantly reduces successful flight hours
- Instrument operating constraints significantly limit science return
- Instrument scientific contribution has been marginalized by newer operational technologies, competing observations, or other factors
- The NASA Strategic Plan has restructured relevant scientific priorities

The SSMO Director and the NASA Project Scientist will organize and co-chair a review of any instrument that is not scientifically productive. The review panel of scientists and Instrument Teams with relevant experience will consider input from the Instrument Team, the general observer community, SSMO science and operations staff, and others, to formulate a recommendation to either retire the instrument, or to continue operations, possibly under specific conditions. If the review results in the recommendation to permanently retire an instrument from SOFIA service, the SSMO Director and NASA Project Scientist will communicate this recommendation to the NASA Program Scientist and the SMD Astrophysics Director for US instruments and to DLR for German instruments, and recommend the final disposition of the instrument and supporting hardware (e.g., to be returned to the developing institution, made available to new developers, placed in storage at NASA, etc.). The NASA SMD Director of Astrophysics has final authority to decide on retirement or replacement of a US SI.

Appendix A: Acronyms

AAS	American Astronomical Society
A/C	Aircraft
AFSRB	Airworthiness & Flight Safety Review Board
ALMA	Atacama Large Millimeter Array
AO	Aircraft Operations
AO	Announcement of Opportunity
AOPS	Aircraft Operations
AOR	Astronomical Observation Request
ARC	Ames Research Center
CCD	Charge Coupled Device
CCR	Configuration Change Request
CDCU	Chopper Driver Controller Unit
CDDS	Cavity Door Drive System
CECS	Cavity Environment Control System
CFP	Call for Proposals
CI	Continuous Improvement
CM	Configuration Management
ConOps	Concept of Operations
COOP	Continuity of Operations
CS	Cycle Scheduler
cvs	Concurrent Versions System
CWR	Counterweight Rack
DAOF	Dryden Aircraft Operations Center
DCS	Data Cycle System
DCT	Data Collection Time
DDT	Director's Discretionary Time
AFRC	Armstrong Flight Research Center
DHB	Armstrong Handbook
DLR	Deutschen Zentrums fur Luft und Ramfart
DR	Discrepancy Report
DSI	Deutsches SOFIA Institut
EAS	European Astronomical Society
EMI	Electromagnetic Interference
Public Outreach	Education and Public Outreach
ERB	Engineering Review Board
ERO	Early Release Observation
ES	Early Science
EXES	Echelon-Cross-Echelle Spectrograph

FAA	Federal Aviation Administration
FCIF	Flight Crew Information File
FCLS	Focused Chopped Light Source
FIFI-LS	Far-Infrared Field Imaging Line Spectrometer
FLITECAM	First Light Infrared Test Experiment Camera
FMS	Flight Management System
FOC	Full Operational Capability
FOM	Flight Operations Manual
FORCAST	Faint Object Infrared Camera for the SOFIA Telescope
FOV	Field of View
FPI	Focal Plane Imager
FSI	Facility Science Instrument Facility-class Science Instrument
FTP	File Transfer Protocol
FUSE	Far Ultraviolet Spectroscopic Explorer
GI	General Investigator
GPU	Ground Power Unit
GREAT	German Receiver
GTO	Guaranteed Time Observation
GUI	Graphical User Interface
HAWC	High-resolution Airborne Wideband Camera
HILS	Hardware-in-the-Loop Simulator
HIPO	High-speed Imaging Photometer for Occultation
HK	Housekeeping
HMV	Heavy Maintenance Visit
HST	Hubble Space Telescope
ICD	Interface Control Document
ICP	Instrument Commissioning Plan
INF	Instrument Flange (vessel)
IPAC	Infrared Processing and Analysis Center
IPT	Integrated Product Team
IR	Infrared
IRR	Instrument Readiness Room
IRSA	Infrared Science Archive
IS	Instrument Scientist
ISF	Initiation of Science Flights
IT	Information Technology
JSPP	Joint SOFIA Program Plan
JWST	James Webb Space Telescope
KAO	Kuiper Airborne Observatory

LAN	Local Area Network
LCHP	Large Chopped Hard Plate
MADS	Mission Audio Data System
MCCS	Mission Controls and Communications System
MCF	Mirror Coating Facility
MD	Mission Director
MOA	Memorandum of Agreement
MOPS	Mission Operations
MOS	Mission Operations System
NASA	National Aeronautics and Space Administration
NPR	NASA Procedural Requirement
ODC	Observatory Data Cache
OIA	Operational Interface Agreements
OPD	Observation Planning Database
PCA	Program Commitment Agreement
PCB	Project Control Board
PCM	Program Control Management
PI	Principal Investigator
PIC	Pilot-in-Command
PIF	Pre-Flight Integration Facility
PMB	Program Management Board
PPBE	Planning, Programming, Budgeting, and Execution
PSI	Principal Investigator-class Science Instrument
QA	Quality Assurance
RAM	Reliability and Maintainability
RH	Research Hour
S&MA	Safety and Mission Assurance
SAFIR	Single Aperture Far-Infrared Observatory
SAFIRE	Submillimeter and Far Infrared Experiment
SCL	SOFIA Command Language
SciOps	Science Operations
SFH	Successful Flight Hours
SFP	Science Flight Planner
SI	Science Instrument
SIAT	Science Instrument Airworthiness Team
SIL	System Integration Laboratory
SIMF	Science Instrument Mounting Flange
SMA	Secondary Mirror Assembly
SMD	Science Mission Directorate
SMO	Science and Mission Operations

SOC	SOFIA Operations Center
SOFIA	Stratospheric Observatory for Infrared Astronomy
SP	Special Performance
SPICA	Space Infrared Telescope for Cosmology and Astrophysics
SPO	Science Project Office
SSC	SOFIA Science Center
SSMO	SOFIA Science and Mission Operations
STEM	Science Technology Engineering and Mathematics
TA	Telescope Assembly
TAAS	Telescope Assembly Alignment Simulator
TAC	Time Allocation Committee
TAIPS	Telescope Assembly Image Processing System
TDSI	Technology Demonstration Science Instrument
TO	Telescope Operator
ToO	Target of Opportunity
USRA	Universities Space Research Association
WISE	Wide-field Infrared Survey Explorer

Appendix B - Definitions

Airborne Astronomy Ambassadors (AAA)
This program involves peer-reviewed applications from teachers and other educators to participate in SOFIA science flights. This program, along with onboard Public Affairs activities (e.g., press, VIPs) are conducted in parallel with science operations and are carefully structured so as not to interfere with the science productivity of SOFIA. Observatory science operations are a focal point for educator, media, and public attention. Educator guests will have an unprecedented opportunity to observe and participate in front-line scientific research as it happens. In particular, educators will work as partners with willing scientists and make non-interfering observations of their own as part of a professional development experience.

Airborne Observatory
The Stratospheric Observatory for Infrared Astronomy (or 'the Observatory' or 'the Airborne Observatory') consists of a uniquely modified Boeing 747SP aircraft and all equipment installed in the aircraft, including a 2.5-meter effective aperture gyro-stabilized Telescope Assembly (TA) integrated with a science instrument (SI) and the subsystems that monitor and control the operation of the observatory (principally, the Cavity Door Drive System (CDDS), the Mission Controls and Communications System (MCCS), and the aircraft's Flight Management System). The Airborne Observatory includes related Ground Support Facilities (GSF) and Ground Support Equipment (GSE) (e.g., mechanical, electrical, optical).

Airborne Operations
Airborne Operations includes Flight Operations and all in-flight activities related to Aircraft Operations, Science Operations, and Mission Operations. The Airborne Operations work element excludes ground-based activities for Aircraft Operations, Science Operations and Mission Operations.

Aircraft (A/C or AC)
The Boeing 747-SP airplane that is modified to accommodate the TA, and other systems, necessary to convert the basic vehicle into an operational flight platform for the SOFIA Program.

Aircraft Operations
Aircraft Operations (AOPS) operational element includes the integrated Aircraft System and TA that serves as the platform for carrying science instrument(s), humans, and other mission-oriented equipment to the mission destination(s) to achieve the mission objectives. The Observatory system includes the basic aircraft subsystems as appropriate: Crew, Power, Command & Data Handling, Telecommunications, Mechanical, Thermal, Propulsion, Guidance Navigation and Control, Wiring Harness, and Flight Software. This element also includes all design, development, production, assembly, test efforts and associated Ground Support Equipment (GSE) to deliver the completed system for integration with the Science Instruments. This element does not include integration and test with Science Instruments and other project systems.

Aircraft System

The AS is the modified NASA (tail number N747NA) 'Clipper Lindbergh' aircraft (AC), all systems and subsystems within the aircraft and all tooling required for the aircraft and all associated AC hardware, not including the Telescope Assembly, Mission Controls and Communications System, and Science Instrument.

Archiver Subsystem (ARS)
The Archiver Subsystem is the storage device for all Observatory data sources. Archive data includes SI data as well as telescope images and associated data acquired from the TA imagers. The Archiver provides storage for all video data delivered from the DVDS and audio data from the MADS. The ARS receives data from the MCCS as well as external subsystems.

Data Acquisition Subsystem (DAS)
Acquires data from sensors and other sources for use on the Observatory.

D-check
D-check is a periodic required aircraft maintenance time, which is based on aircraft flight hours and involves larger, more complex checks of the aircraft (structural inspections, etc.). Usually requires a more extended downtime than typical maintenance activities.

Data Cycle System (DCS)
Provides tools and infrastructure for both General Investigators (GIs) and Science and Mission Operations (SMO) staff for proposal preparation and submission, observation and mission planning, observation execution, and data archiving and distribution. Archived SOFIA science data may be accessed in the DCS by members of the public and SOFIA GIs. Only the appropriate GIs will have access to data within the proprietary period.

Data Processing System (DPS) / Pipeline
Provides tool to process and calibrate Facility Science Instrument data. Prior to the science flights, Guest Investigators (GIs) may visit the SSC to understand the data pipelines and data processing options. Details of the data reduction and calibration process will be made available to all GIs from pipeline scientists at the SSC.

Digital Video Distribution Subsystem (DVDS)
Streaming video data from multiple sources are captured and recorded by the DVDS throughout each flight. Video cameras are located in the telescope cavity and the CSEB to monitor unmanned areas of SOFIA during flight. Additional video cameras are located throughout the pressurized crew cabin to record Observatory operations activities and provide enhanced situational awareness. These video sources are available at workstations during flight and are also recorded for archiving.

DSI Computer Laboratory
SSC in Building 211, Room 116. This laboratory is used for miscellaneous work by the DSI. It is currently used for FPI+ controller tests and storage and tests of DSI's mobile auxiliary telescopes. The lab is equipped with a small ESD workplace and a GPS antenna for component testing.

DSI Optics Laboratory
SSC in Building 211, Room 125. The optics laboratory is a windowless room and therefore suited well for camera and optics tests of different kinds. The laboratory also is equipped with a VIS/NIR spectrometer which allows spectral transmission or reflection measurements of optical samples from 350 nm – 1650 nm.

DSI Thermal Vacuum Test Laboratory
SSC in Building 211, Room 129. A 24" x 24" x 30" Test chamber allows simulation of stratospheric conditions and is being used to qualify technical equipment for the use on SOFIA.

Education and Public Engagement
Engaging and alerting the public regarding mission activities and achievements via channels such as mission public websites, social media postings and broadcasts, podcasts, Google+ "hangouts", and also public talks and exhibits. Generally occurs outside of formal and informal educational settings. [NASA HQ Offices of Communication & Education have changed the name of "Public Outreach" to "Public Engagement." In response to government-wide spending cuts, NASA's STEM (Science, Technology, Engineering, and Mathematics) educational programs may be re-defined in FY2014].

Education and Public Outreach
EPO is one of the functions provided by the SOFIA Program designed to make significant and measurable contributions to meeting national goals for the reform of science, mathematics, and technology education and for the general elevation of scientific and technological literacy. [NASA HQ Offices of Communication & Education is rebranding "Public Outreach" as "Public Engagement."]

Engineering and Maintenance
Engineering and Maintenance operational element encompasses the specialized engineering tasks associated with general periodic maintenance, as well as supporting specialized engineering tasks for issues that may arise. Engineering and Maintenance is responsible for SI Labs and Pre-Flight Integration Facility management. SI receiving and processing, SI installation, and removal fromteh TA, TAAS operations, TA optics maintenance and cleaning, the Mirror Coating Facility, and assisting the German partner with TA engineering and maintenance.

EXES (Echelon Cross Echelle Spectrograph)
EXES is a first-generation PI-Class Science Instrument developed by University of Texas at Austin, UC Davis and NASA Ames as a high-resolution cross-dispersed echelle spectrometer operating from 4.5–28.5 μm with three resolving modes: R~105, R~104, and R~2000. The detector is a Raytheon Vision Systems Si:As 1024×1024 array.

EXES Science Instrument Laboratory:
SSC in Building 211, Room 121. Provides virtual and physical infrastructure to test the SI interfaces with the Observatory systems. From the SI lab, an instrument may connect to a SIL,

which models Observatory and support components. The SI Development Laboratory provides facilities for instrument and technology development and detector characterization in a controlled environment. The lab includes clean-room facilities, static-controlled work areas, oxygen monitoring suitable for cryogenic instrument servicing, and a fully functional telescope assembly alignment simulator (TAAS).

FAA (Federal Aviation Administration)
The Federal Aviation Administration is the national aviation authority of the United States of America. An agency of the U.S. Department of Transportation, it has authority to regulate and oversee all aspects of American civil aviation.

FIFI-LS (Far-Infrared Field-Imaging Line Spectrometer)
FIFI-LS, a first-generation PI-class Science Instrument developed by the University of Stuttgart, is an integral field imaging spectrometer with simultaneous observing in two channels from 50-125 µm and 105-210 µm. Two independent grating spectrometers share a common field of view through a dichroic beam-splitter. Each spectrometer has a 16×25 Ge:Ga photoconductor array; the long wavelength array is stressed. Each channel has a field of view with 5×5 spatial pixels, with a plate scale of 12″ per pixel in the red channel, and 6″ per pixel in the blue channel. The integral field unit maps the 5×5 spatial pixels onto the 25-pixel rows on each detector, while the grating spectrometer disperses the spectra onto the 16-pixel columns. The spectral resolving power of each channel varies between R ~ 1000–4000. FIFI-LS is expected to transition to a facility instrument in 2015.

Flight Manager Subsystem (FM)
Provides flight plan tracking (comparison of planned vs. actual), automatic aircraft heading control, and in-flight re-planning capabilities.

FLITECAM (First-Light Infrared Test Experiment CAMera)
FLITECAM, a first-generation Facility-class Science Instrument developed by UCLA, is a 1.0–5.5 µm wide-field imager with grism spectroscopy. The detector is an indium antimonide (InSb) Raytheon Aladdin III 1024×1024 array. FLITECAM uses refractive optics to provide an 8′ diameter field of view. A selection of filters provide narrowband and broadband photometry, and a selection of three grisms and 2 slits provide medium-resolution spectroscopy with R ~ 800–1800. It is capable of mounting solo or co-mounting with HIPO in the FLIPO configuration, providing simultaneous data acquisition at two optical wavelengths (HIPO) and one near-IR wavelength (FLITECAM).

Facility Science Instrument (FSI)
Instruments that are routinely operated and maintained by designated SSMO FSI scientists, in support of General or Guest Investigators. FSIs are general-purpose, reliable instruments for which the process of data acquisition, reduction, and calibration is straightforward and which will routinely support observations by GIs, with assistance from an SSMO scientist.

Flight Operations

Flight Operations begins with pre-flight activities, which are typically conducted within 24 hours of a science flight. The Mission Operations tem finalizes the mission plan and associated data, then transfers the flight datasets to the aircraft. The Mission Opeartions group then verifies the mission systems are properly configured for flight. Aircraft Operations files the finalized flight plan with the FAA and performs pre-flight checks, fueling, and towing of the SOFIA aircraft. Once the aircraft is airborne, the Mission Operations team leads the science data collection, with support from Science Operations to operate the Facility-class Science Instrument (FSI) or the PI team to operate a Principal Investigator-class Instrument (PSI). Aircraft Operations is responsible for piloting the aircraft safely through the in-flight operations. Once the aircraft has landed, the MOPS team is responsible for transferring all flight data off the aircraft. The Aircraft Operations group tows the aircraft back to the hangar and performs post-flight checks.

Flight Management Infrastructure (FMI)
The Flight Management Infrastructure (FMI) is the software designed to keep the aircraft from interfering with preplanned observations on the sky. The FMI allows the planning and execution of SOFIA missions in the presence of a large number of external constraints (e.g., restricted airspace, international boundaries, elevation limits of the telescope, aircraft performance, winds at altitude, and ambient temperatures). The FMI includes the Cycle Scheduler and the Flight Planner / Executor:
Cycle Scheduler (CS): The CS software consists of a collection of scheduling tools, which can generate or update observatory long-term schedules, based upon constraints, pre-existing schedules and user-specified parameters.
Flight Planner / Executor: Used to first plan, then execute and track SOFIA flights. It defines the aircraft flight path required to observe the scientific targets and tracks the planned versus actual path of the aircraft in flight to support adjustment and re-planning.

FORCAST (Faint Object InfraRed CAmera for the SOFIA Telescope)
FORCAST is a first-generation Facility-class Science Instrument developed by Cornell University with simultaneous dual-channel 5–40 μm imaging and grism spectroscopy. Each channel consists of a 256×256 pixel array that yields a 3.2′ field-of-view with 0.75″ pixels. The short wave camera (SWC) uses a Si:As blocked-impurity band (BIB) array optimized for $\lambda < 25$ μm, while the long wave camera (LWC) uses a Si:Sb BIB array optimized for $\lambda > 25$ μm. Spectroscopy is provided using a suite of six grisms, with long slit, low spectral resolution (R ~ 200) capability from 5–40 μm and cross-dispersed, high spectral resolution (R ~ 800–1200) capability from 5–14 μm.

Full Operational Capability
At Full Operational Capability (FOC), the SOFIA shall demonstrate full science operational capability with four available instruments (Program Commitment Agreement, SOF-HQ-PD-PM91-0001, October 2010)

GREAT (German REceiver for Astronomy at THz Frequencies)
GREAT is a first-generation PI-class Science Instrument developed by the Max-Planck-Institut für Radioastronomie capable of providing high-resolution heterodyne spectroscopy in bands at 1.3, 1.5, 1.9, 2.5, 2.7, and 4.7 THz. Two mixers and three local oscillators may be installed for

any given flight, providing access to two or three channels depending on the configuration for that flight. A polarizing beam splitter allows simultaneous measurements in two of the installed channels. An enhancement is currently in development that will add three 7-pixel heterodyne receiver arrays with one flight configuration covering all channels.

Ground Support Equipment (GSE)
The equipment (mechanical, electrical, optical, etc.) employed in ground support of the Airborne Observatory and integration and testing of the Airborne Observatory elements. GSE is categorized with the system element that operates it.

Ground Support Facilities (GSE)
The GSF protects the Airborne Observatory (AS, TA, and SIs) and any spares, repair parts, test and support equipment, and simulators requiring protection, including those of the TA. The GSF also provides all offices, work areas, shops, documentation facilities, and other facilities necessary to support the SOFIA flight and ground operations and maintenance staff, including for TA.

Ground Support System
The Ground Support System includes the Ground Support Facilities (GSF) and the Ground Support Equipment (GSE).

Ground Systems
The complex of equipment, hardware, software, networks, and mission-unique facilities required to conduct mission operations of the observatory and science instruments. This complex includes the computers, communications, operating systems, and networking equipment needed to interconnect and host the Mission Operations software. This element includes the design, development, implementation, integration, test and the associated support equipment of the ground system, including the hardware and software needed for processing, archiving and distributing telemetry and radiometric data. This element does not include integration and test with the other project systems, nor does it include conducting mission operations.

HAWC+ (High-resolution Airborne Wideband Camera+)
HAWC+ is a second-generation Facility-class Science Instrument originally developed at University of Chicago and undergoing an upgrade at JPL. HAWC is a 50–240 μm imager and polarimeter, providing broadband imaging and polarimetry at 53, 63, 89, 155, and 216 μm. An optics carousel provides for diffraction-limited imaging at each of the 5 bands. Two orthogonal polarization states are measured simultaneously using a wire grid polarizing beam-splitter and a pair of background-limited backshort-under-grid (BUG) 64×40 detector arrays.

Hardware-in-the-Loop Simulator (HILS) Labs
1) The Development HILS Lab allows development and informal testing of the MCCS without the dedicated use of the Observatory. It also supports 747-SP platform simulation development and a TA hardware/software development environment. The Lab uses flight-equivalent hardware (non-ruggedized) for the Platform Interface Subsystem (PIS), TA Image Processing Subsystem (TAIPS), Data Acquisition Subsystem (DAS), Archiver, time server, and Workstation Subsystem

(WS). 2) The Verification and Validation (V&V) HILS Lab is used for formal MCCS V&V activities. This provides the ability to conduct mission rehearsals and to perform Telescope Operator and Mission Director training. The Lab makes use of flight spare hardware for the PIS, TAIPS, DAS, Archiver, time server, WS, and network.

HIPO (HIgh-speed Photometer for Occultations)
HIPO is a first-generation Special-purpose Science Instrument developed by Lowell Observatory with dual-channel high-speed imaging photometry from 0.3–1.1 μm with a pair of e2v 1024×1024 CCD arrays. HIPO can be used as a platform for co-mounting of FLITECAM in the FLIPO configuration.

Mirror Coating Facility (MCF)
Designed to support coating the primary TA mirror. The MCF includes the handling and support structures, mirror coating chamber, in-situ mirror cleaning equipment, and additional ground support equipment.

Mission Audio Data Subsystem (MADS)
The Mission Audio Distribution System is the primary system for controlling and distributing audio data throughout the Observatory. It consists of commercial off the shelf (COTS) products, connected by a fiber optic multiple channel communication system that allows crew members and operators to communicate with each other. The MADS hardware consists of several data hubs that are connected to audio connection panels located at crew stations. Crew members connect to the MADS using headsets that are plugged into the connection panels. The MADS system itself is controlled via a control panel. The MADS also interfaces with the flight deck and the aircraft intercom system. Every seat and crew station has MADS panels which allow the user to monitor multiple audio channels and talk on one. The primary channels are recorded to the data archive.

Mission Controls and Communication System (MCCS)
Provides mission communication, power distribution, data acquisition, data archival, network services, and Observatory crew interfaces. The MCCS itself is comprised of the following subsystems: Power Distribution Subsystem (PDS), Mission Audio Data Subsystem (MADS), Platform Interface Subsystem (PIS), Data Acquisition Subsystem (DAS), Digital Video Distribution Subsystem (DVDS), TA Image Processing Subsystem (TAIPS), Video Processing and Recording Subsystem (VPARS), Archiver Subsystem (ARS), Workstation Subsystem, Flight Manager Subsystem (FM).

Observatory
The Stratospheric Observatory for Infrared Astronomy (or 'the Observatory' or 'the Airborne Observatory') consists of a uniquely modified Boeing 747SP aircraft and all equipment installed in the aircraft, including a 2.5-meter effective aperture gyro-stabilized Telescope Assembly (TA) integrated with a science instrument (SI). The Airborne Observatory includes related Ground Support Facilities (GSF) and Ground Support Equipment (GSE) (e.g., mechanical, electrical, optical).

Observatory System
The Observatory System consists of a modified Boeing 747-SP aircraft, which houses the equipment necessary for infrared (IR) astronomy. The primary components of the system are the TA, which focuses the astronomical image onto the Science Instrument, which collects the IR data. The MCCS controls the functionality of the Observatory and interfaces with the aircraft, TA, and SI. The scientific and mission data collected during flight is packaged by the MCCS and archived in the DCS. The DCS serves as the primary interface for the users performing investigations using SOFIA, both for proposals and to access the collected data. The DCS is also the core science system that collects the proposal and observing target information that is used to create flight and mission plans.

Outreach
The combination of mission communication modes to the rest of the world: Education, Public Engagement, Public Affairs, and Science Outreach. [NASA HQ Offices of Communication & Education are moving us toward renaming "Public Outreach" as "Public Engagement."]

Platform Interface Subsystem (PIS)
The Platform Interface Subsystem acts as the data processing and control hub for the entire Observatory. It collects and processes data from various elements of the Observatory and then distributes the processed data to subscribers. The PIS receives, validates, and interprets commands from the MCCS and user workstations and routes the interpreted commands to the appropriate Observatory subsystems. The subsystem data and SCL commands are also archived by the PIS for inclusion in the flight data set.

Power Distribution Subsystem (PDS)
Distributes alternating and direct current power to Observatory systems as well as an uninterruptible power source (UPS) for critical systems.

Pre-flight Integration Facility (PIF)
Allows SI teams to perform alignment and fit checks with a TA interface outside of the aircraft. The PIF provides an opportunity to verify the SI weight, SI center of gravity, SI pupil alignment, and bore-sight location.

PI-class Science Instrument (PSI)
A general-purpose instrument that is developed and maintained at the state of the art throughout its operating life. PSIs are used for observations by the instrument team and General or Guest

Investigators, but are operated and maintained by the builder of the instrument, not by SSMO scientists.

Program Management
The business and administrative planning, organizing, directing, coordinating, controlling, and approval processes used to accomplish overall Program objectives, which are not associated with specific hardware or software elements. This element includes reviews and documentation; non-program owned facilities, and program reserves, as well as public affairs. It excludes costs associated with technical planning and management, and costs associated with delivering specific engineering, hardware and software products.

Public Affairs (PA)
News releases, media relations, public relations.

Public Engagement
Engaging and alerting the public regarding mission activities and achievements via channels such as mission public websites, social media postings and broadcasts, podcasts, Google+ "hangouts", and also public talks and exhibits. Public Engagement generally occurs outside of formal and informal educational setting and has only modest or diffuse educational components and goals. [The content of SOFIA Public Engagement is under review given the changes specified in the President's Fiscal Year 2014 Budget Request.]

RSSO (Ready for Sustained Science Observations)
Program Level-1 Milestone "Ready for Sustained Science Observations (RSSO)"
Replaces Full Operational Capability (FOC) milestone, which is obsolete.
Milestone marks the beginning of science observations with all Generation-1 science instruments commissioned, all aircraft observatory systems integrated per the Level-1 requirements and the program staffed to support the maximum Research-Hour requirement.

Safety and Mission Assurance (S&MA)
The technical and management efforts of directing and controlling the S&MA elements of the Program. This element includes design, development, review, and verification of practices and procedures and mission success criteria intended to assure that the delivered observatory, ground systems, mission operations, and payload(s) meet performance requirements and function for their intended lifetimes. This element excludes mission and product assurance efforts at partners/ subcontractors other than a review/oversight function, and the direct costs of environmental testing, as applicable.

Science Instrument (SI)
The Science Instrument consists of a focal plane assembly mounted to the TA Instrument Mounting Flange, support electronics installed in the aircraft cabin in the counter weight rack and the investigator station in the Experimenter Racks, and all associated cabling excluding those cables associated with patch panels and cable load alleviator. The science instruments are those items designed for astronomical observations aboard the airborne system and is developed by a science instrument team.

Science Mission Operations
The Science Mission Operations (MOPS) element covers the management of the development and implementation of personnel, procedures, documentation and training required to conduct science mission operations. This element includes the receiving and processing of telemetry data, monitoring and analyses of observatory system status, flight path planning and monitoring, and mission planning for and operation of the Telescope Assembly for target acquisition and pointing. It includes maintenance, repair, checkout, calibration, operation and logistical support for all aircraft, science and mission systems on the observatory and in the SSC/SOC, whether on the ground or in flight from local or remote bases.

Science Instrument Readiness Rooms
These 5 laboratories contain support facilities where the science instruments are maintained and tested. Cryogen support, Electrostatic Discharge benches, and necessary tools are all supported in each lab. From the SI labs, an instrument may connect to the SOC SIL, which allows software testing with the instrument in the loop.

Science Outreach (SO)
Promoting SOFIA to the scientific community.

SOFIA Operations Center (SOC)
The SOFIA Operations Center (SOC) is a Ground Support Facility at the NASA Armstrong Flight Research Center (AFRC) in the Armstrong Aircraft Operations Facility (DAOF) Hangar 703 in Palmdale, California.
Personnel with a home base at the SOC include NASA's prime contractors for the execution and implementation of SOFIA aircraft and flight operations, the NASA program management and related support contractors. The SOC also is home to science mission operations support personnel.
Aircraft and flight operations are based at the SOC, where the SOFIA aircraft resides. The aircraft, telescope assembly (TA), and commissioned Facility-class Science Instruments (FSIs) are maintained at the SOC. Science mission operations are supported at the SOC, including science instrument integration into the Observatory.
Key ground support facilities at the SOC include:

- Science instrument readiness rooms (IRRs)
- Pre-flight Integration Facility (PIF), including TAAS
- Systems Integration Laboratories (SILs)
- Hardware-in-the-Loop Simulators (HILS)
- Mirror Coating Facility (MCF)

SOFIA Science Center (SSC)
The SOFIA Science Center (SSC) is a Ground Support Facility at the NASA Ames Research Center (ARC) in the Sustainability Base (Building 232) and Building 211 at Moffett Field in Mountain View, California.

Personnel with a home base at the SSC include NASA's prime contractor for the execution and implementation of SOFIA Science Mission Operations (SSMO), the NASA program management and related support contractors.
At the SSC, the prime SSMO contractor performs work related to the preparation, solicitation, evaluation, and selection of observation proposals; planning and sequencing of observations; science flight planning; science mission operations; the processing, archiving, and distribution of science data; and public engagement and science community outreach.
Key ground support facilities at the SSC include:

- SSMO server
- DSI computer laboratory
- DSI optics laboratory
- DSI thermal vacuum test laboratory
- EXES science instrument laboratory
- Systems Integration Laboratories (SILs)

Science Operations
The Science Operations (SciOps) element includes the managing, directing, and controlling of the science investigation aspects, as well as leading, managing, and performing the technology demonstration elements of the Program. Specific responsibilities include defining the science or demonstration requirements; prioritization of Science Targets, ensuring the integration of these requirements with the science instruments and Observatory; ground systems, and mission operations; providing the algorithms for data processing and analyses; and performing data analysis and archiving. This element includes the management of the Guest Investigator (GI) program. This element excludes responsibility for hardware and software for on-board science investigative instruments.

SOFIA Science and Mission Operations
The SOFIA Science and Mission Operations (SSMO) work element is managed by a contractor based at the SOFIA Science Center (SSC). The contractor for this work element is called the "SSMO" throughout this document. The SSMO is responsible for the development and maintenance of science and mission operations systems and facilities at both the SOFIA Science Center (SSC) and the Science Operations Center (SOC). The SSMO is responsible for all activities, procurements, and manpower associated with the development and execution of the integrated plan and systems for bringing the SSMO into operation. This element includes the development of the Mirror Coating Facility (MCF), mission facilities, science laboratories, simulation facilities and network infrastructure. This element includes development of the science flight planning software; the development of the Data Cycle System (DCS) software and hardware, including the data archive hardware; the development of the Data Processing System (DPS); the simulation labs; the information systems infrastructure; the move, re-installation and re-commissioning of the MCF.

Systems Engineering and Integration
The technical and management efforts of directing and controlling an integrated engineering effort for the program. This element includes the efforts to define the observatory - ground system, conducting trade studies; the integrated planning and control of the technical program

efforts of design engineering, software engineering, specialty engineering, system architecture development, and integrated test planning, system requirements writing, configuration control, technical oversight, control and monitoring of the technical program, and risk management activities. Documentation Products include mission/system requirements document; Interface Control Documents (ICDs); Risk Management Plan and verification and validation plan. Excludes any design engineering costs.

TA Image Processing Subsystem (TAIPS)
The TAIPS processes the raw imager data into logged data, which is saved in FITS format, and archived in the Archiver.

Telescope Assembly Alignment Simulator (TAAS)
Located in the PIF, the TAAS is used to perform fit checks of SIs using a duplicate of the TA Flange Assembly that permits adjustments, checkout, testing, and characterization of SIs prior to installation and use aboard the Observatory.

Systems Integration Laboratories (SIL)
Three SSC Systems Integration Laboratories (SILs): SSC in Building 232, Room 133. One is the primary development platform for observatory-related software and uses the same flight hardware and operating system releases as the flight system. The second and third SILs are used for development, training, and testing purposes (e.g., checking TA command interfaces, confirming data acquisition, and evaluating new concepts). SIL software installations are adaptable to three software configurations: 1) baseline aircraft, 2) version under test, and 3) evaluation (e.g., uncontrolled).
Telescope Operators (TOs) and Mission Directors (MDs) perform mission planning tasks and SOFIA mission crew training using the SIL. The SIL also has the capability to simulate Observatory functionality to prepare for science missions; this includes developing and executing observing scripts, practicing communication paths, and executing flight plans.
One SOC Systems Integration Laboratory (SIL): This SIL is used for development, training, and testing purposes (e.g., checking TA command interfaces, confirming data acquisition, and evaluating new concepts).

TAAU
The TAAU is the main physical structure of the TAAS, which allows the SI to be attached at one end and the infrared sources at the other (see Figure 1). The TAAU consists of the INF vessel, Nasmyth tube, and Adjustable Source Mounting Flange (ASMF). The scale of the TAAU is designed so that the optical path length is 43% of the SOFIA Telescope Assembly's (TA) optical path length from the nominal focus to the TA secondary mirror.

LCHP
The TAAS will have three different infrared sources: the LCHP to simulate a "hot" secondary mirror for pupil imagers, a SCHP used mainly to map a SIs beam profile, and a FCLS which acts as a "point-like" source for focusing and alignment to the SI chip.

FCLS

The FCLS will include actuators for control of focus position, aperture position, and X-Z translation.

SCHP
The SCHP will include actuators for control of X-Z translation.

SSMO Server
The SOFIA Science Center Server that runs the SOFIA Science Mission Operations network is located in Room 231 and Room 123 in N211.

TASim (Telescope Assembly Simulator)
The TASim is designed to simulate the Telescope Assembly dynamics and software interfaces to the MCCS. Developed at the Science Center, it is used in the SIL and HILS environments for development, verification and validation activities for the MCCS PIS, TAIPS, and Workstation GUI, for MCCS integration with SIs and for mission planning purposes.

Telescope Assembly (TA)
The Telescope Assembly (TA) is part of the overall Airborne Observatory, and consists generally of the Optical Assembly, the Structural Assembly, the Suspension Assembly, the Flange Assembly, the Pointing and Control Subsystem, the Electrical Subassembly, the Ground Support Equipment and all associated software.

Video Processing and Recording Subsystem (VPARS)
Handles streaming video data from: workstation displays, video generators in VPARS, Observatory cameras for situational awareness, and (optionally) from SI computers (to allow sharing of video with others onboard).

Verification and Validation
Activities of Inspection, Test, Demonstration, or Analysis.

Workstation Subsystem (WS)
Provides a configurable user interface for the mission crew.